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GROUNDWATER FATE AND TRANSPORT EVALUATION REPORT SOUTH CAVALCADE SUPERFUND SITE HOUSTON, TEXAS

Prepared for:

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August 1997

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VIA FEDERAL EXPRESS

August 5, 1997

Mr. Glenn Celerier, P.E.
EPA Project Coordinator (6SF-AT)
Texas Construction Section, Superfund Programs Branch
U.S. Environmental Protection Agency, Region VI
Allied Bank Tower and Fountain Place
1445 Ross Avenue
Dallas, Texas 75202-2733

Re: Groundwater Fate and Transport Evaluation Report
South Cavalcade Superfund Site

Dear Mr. Celerier:

Please find enclosed for review and approval by the U.S. Environmental Protection Agency (EPA), three copies of the revised Groundwater Fate and Transport Evaluation Report for the South Cavalcade Superfund Site located in Houston, Texas. The Groundwater Fate and Transport Evaluation Report was revised in accordance with the July 11, 1997 Response to Comments submittal prepared by Beazer to address the EPA comments on the Draft Report dated March 1997. Also, the modifications agreed upon among representatives of Beazer and EPA during the subsequent teleconferences on July 22 and 23, 1997 have been incorporated into the report.

Beazer looks forward to the EPA review and approval of this submittal. Following completion of your review and approval, please contact me to discuss a schedule for preparation and submittal of a work plan for the verification activities proposed in the report. In the meantime, please call me at (412) 227-2174 if you have questions regarding this submittal.

Sincerely,

Michael Slenska, P.E.
Environmental Manager

cc: R. Lucas - Beazer
G. Chavarria - Chief, Texas Construction Section, EPA Region VI
J. Weisberg - EPA Region VI
T. Collins - TNRCC
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bcc: Gary Hokkanen - GeoMatrix
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GROUNDWATER FATE AND TRANSPORT EVALUATION REPORT SOUTH CAVALCADE SUPERFUND SITE HOUSTON, TEXAS

1.0 INTRODUCTION

This document presents the results of an evaluation of the fate and transport of select dissolved constituents in shallow groundwater at the South Cavalcade Superfund Site (Site) in Houston, Texas. The location of the Site is shown on Figure 1. This report was prepared by KEY Environmental, Inc. (KEY) on behalf of Beazer East, Inc. (Beazer) to present an evaluation of potential future groundwater exposure scenarios at the above-referenced Site. The fate and transport evaluation presented herein was performed in accordance with the technical approach and scope of work presented in the *Groundwater Fate and Transport Evaluation Work Plan* (Work Plan) dated October 1996[1]. The Work Plan was approved by the United States Environmental Protection Agency (EPA) on October 16, 1996[2].

1.1 Purpose

The objective of the groundwater fate and transport evaluation is to assess whether any realistic potential risk to human health and the environment exists currently, or in the future, with respect to reasonable potential exposure to dissolved constituents in the shallow groundwater. The groundwater fate and transport evaluation involves an assessment of the natural attenuation of select dissolved phase constituents in groundwater in the shallow aquifer. This evaluation was completed to determine whether natural processes (e.g, adsorption, dispersion and biodegradation) are effective in reducing the concentrations of dissolved phase constituents to health-protective levels before shallow groundwater potentially containing such constituents may, in the future, migrate from the Site and reach locations where potential future groundwater exposure could realistically and reasonably occur. The results of the groundwater fate and transport evaluation provide the technical

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1 KEY Environmental, Inc., October 1996. *Groundwater Fate and Transport Evaluation Work Plan, South Cavalcade Superfund Site, Houston, Texas.*

2 U.S. Environmental Protection Agency, October 16, 1996. *Fax Transmitted Memorandum to Mike Slenska, Beazer East, Inc. Regarding EPA Review Comments on the South Cavalcade Street Superfund Site Groundwater Exposure Assessment Work Plan, September 1996.*

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basis for the exposure evaluation necessary in order to recommend changes to the current groundwater remedy.

The remedial goals for groundwater specified in the 1988 ROD are summarized in Table 1. According to the ROD, the remedial goals for groundwater were selected to comply with Federal Drinking Water Standards, National Pollutant Discharge Elimination System (NPDES) Best Available Technology Requirements, and Texas Water Quality Standards, which are identified in the ROD as applicable and relevant and appropriate requirements (ARARs). However, since the issuance of the ROD for the South Cavalcade Site, EPA has implemented fundamental changes in the Superfund program approach to groundwater remediation at sites where it is technically impracticable to restore groundwater to drinking water standards.

As indicated in the July 31, 1995 memorandum from Elliott Laws, EPA Assistant Administrator, to the EPA Regional Administrators[3], these situations (e.g., sites where dense non-aqueous phase liquids exist) warrant the use of a waiver of Federal and State groundwater clean-up standards by EPA and "a flexible phased approach to groundwater remediation such as use of interim RODs, no action alternatives, natural attenuation, Technical Impracticability (TI) waivers, etc." Dense non-aqueous phase liquids (DNAPLs) exist within the shallow groundwater bearing unit at the South Cavalcade Site and thus preclude attainment of the groundwater remedial goals. Therefore, a waiver of the remedial goals for groundwater, and implementation of a flexible approach to groundwater remediation, as described in the July 31, 1995 EPA memorandum, may be appropriate if the exposure evaluation, supported by a protective natural attenuation assessment, demonstrates that shallow groundwater does not present an unacceptable current or potential future risk to human health and the environment.

1.2 Fate and Transport Evaluation Technical Approach

The approach established in this fate and transport evaluation to attain the above-described objective is three-fold and includes the following steps:

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[3] U.S. Environmental Protection Agency, July 31, 1995. *Memorandum from Elliot Laws, Assistant Administrator, to Regional Administrators Region I - X Regarding Superfund Groundwater RODs: Implementing Change This Fiscal Year.*

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- **Review of Site Specific Data and Completion of Conceptual Model** - *This comprises the presentation of site-specific geologic, hydrogeologic, DNAPL occurrence, and land use information; which are integrated into a Conceptual Site Model. This Conceptual Site Model forms the basis of completing the simulations that evaluate the fate and transport of chemical constituents in shallow groundwater to hypothetical future shallow groundwater users considering reasonable potential future exposure scenarios.*

- **Simulation of Chemical Constituent Transport**- *This step involves conducting several analytical simulations that evaluate the natural processes (i.e., adsorption and biodegradation) that would potentially impact the migration of chemical constituents in shallow groundwater from potential source areas to hypothetical future shallow groundwater users considering reasonable potential future use exposure scenarios. Section 3.3.1 provides discussion of boundary conditions which presents more detail regarding these scenarios.*

- **Exposure Observations** - *This step summarizes the results of the above two steps and provides observations with regard to the potential for exposure to hypothetical future users of shallow groundwater considering reasonable potential future exposure scenarios.*

1.3 Report Organization

The following section (Section 2.0) presents Site background information and a Site conceptual model. The Site conceptual model summarizes the following information:

- physical Site characteristics;
- past, current and reasonable future land use;
- current and reasonable future groundwater usage;
- Site hydrogeologic conditions;
- inferred distribution of DNAPL;
- nature and extent of Site constituents of interest (COIs) in groundwater;

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- physical and chemical characteristics of the COIs.

Section 3.0 presents the technical approach and methodologies used to complete the fate and transport evaluation. Input parameters used in the analytical simulations are identified and references are provided. Section 4.0 presents the results of analytical fate and transport simulations. Conclusions and recommendations are presented in Section 5.0.

2.0 DEVELOPMENT OF CONCEPTUAL SITE MODEL

This section provides the detailed basis for the development of the Conceptual Site Model. Site-specific information relevant to this shallow groundwater fate and transport evaluation is evaluated in detail below. The majority of this information was obtained during the RI and pilot testing programs. Thereafter, this information is integrated into the Conceptual Site Model, which provides a concise description of the significant facets of the Site and their interrelation to each other. The Conceptual Site Model serves as the basis for the fate and transport evaluation and groundwater exposure assessment. As necessary, the Conceptual Site Model is supplemented by information presented in the peer-reviewed technical literature.

2.1 Site Background Information

A detailed discussion of Site background information which provides the basis for the Conceptual Site Model is provided below.

2.1.1 Site Setting and Operating History

The South Cavalcade Site occupies approximately 66 acres of urban land approximately three miles north of downtown Houston, Texas. The site is rectangular in shape with a length of approximately 3,400 feet (in the north-south direction) and a width of approximately 900 feet (in the east-west direction). A site base map is provided as Figure 2.

The Site was operated as a wood treating plant from 1910 until 1962. Creosote and various metal salts were utilized in the wood treating processes. The wood treating process area was located in the southern portion of the Site along Collingsworth Street. Koppers Company, Inc. (Koppers), now known as Beazer East, Inc. (Beazer), operated the wood treating facility from 1944 until closure in 1962. A coal tar distillation plant was operated by Koppers on the southeastern portion of the Site from about 1944 until 1962. Since the discontinuation of these operations, several trucking firms have occupied the property.

Land use in the vicinity of the Site is a mixture of commercial, industrial and residential. Industrial and commercial properties are located to the east and across Collingsworth Street to the south of

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the Site. The North Cavalcade Superfund Site, which is also the location of a former wood treating facility, is located directly across Cavalcade Street to the north of the Site. Active rail lines immediately border the Site boundaries to the east and the west. The nearest residences are located several hundred feet to the west of the Site.

The Site is currently occupied by three separate trucking firms; thus, much of the ground surface, especially in the southern and northern portions of the Site, is covered by concrete or asphalt pavement or buildings as shown on Figure 2. The central portion of the Site is currently undeveloped. The groundwater treatment facility is located along the eastern Site boundary in the central portion of the Site. Continued future use of the Site properties for non-residential purposes is to be reasonably expected.

According to the RI Report, the area surrounding the South Cavalcade Site is suited to industrial activities due to its close proximity of transportation corridors including, active rail lines, Interstate 610, Interstate 45 and U.S. Highway 59. Information presented in the RI Report indicates a decline in population and households in the vicinity of the South Cavalcade Site. Housing vacancy rates in the vicinity of the Site are reported to be significantly greater than the average rate for the City of Houston. A continued decline in total population and households in the vicinity of the Site is expected in the future according to the RI Report.

2.1.2 Environmental Investigation and Remedial Activities

In 1983, the Houston Metropolitan Transit Authority investigated the Site for potential mass transit use. Results of this investigation indicated localized areas of potential impact and the Site was subsequently referred to the Texas Department of Water Resources (TDWR). In April 1984, TDWR recommended to EPA that the Site be placed on the National Priorities List (NPL). In October 1984, EPA proposed that the Site be added to the NPL. The Site was formally included on the NPL in June 1986.

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In March 1985, Koppers entered into an Administrative Order on Consent to conduct a Remedial Investigation/Feasibility Study (RI/FS) at the Site. The RI/FS was completed by Koppers in August 1988 with submittal of the *Remedial Investigation Report*[4] and the *Feasibility Study Report*[5] to EPA.

The ROD was subsequently issued by EPA in September 1988 and presented the selected remedial alternatives for Site soil and groundwater. The selected remedial alternative for groundwater included extraction and treatment of groundwater containing constituent concentrations greater than the remedial goals. The ROD stipulated that groundwater extraction will continue until constituents have been recovered to the maximum extent possible, as determined through the Remedial Action, based upon experience in operating the groundwater collection and treatment system. The ROD specified that once EPA had determined that groundwater constituents have been recovered to the maximum extent possible, operation of the groundwater collection and treatment system would cease and remaining constituents would be allowed to naturally attenuate to background levels.

The Detailed Statement of Work for Remedial Design/Remedial Action (SOW)[6] was completed by EPA in May 1990. The SOW described the remedial design and remedial action (RD/RA) activities to be performed by Beazer including pilot study tasks to support the design of the selected remedies. In March 1991, Beazer entered into a Consent Decree[7] with EPA for implementation of the RD/RA activities specified in the SOW. The SOW was subsequently incorporated into the EPA-approved *Remedial Design Work Plan* (RDWP)[8] prepared by Bechtel Environmental, Inc. (Bechtel) on behalf of Beazer dated March 1992.

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4 Keystone Environmental Resources, Inc., July 1988. *Final Report - Remedial Investigation, South Cavalcade Site, Houston, Texas.*

5 Keystone Environmental Resources, Inc., August 1988. *Feasibility Study , South Cavalcade Site, Houston, Texas.*

6 U.S. Environmental Protection Agency, May 1990. *Remedial Design Detailed Statement of Work, South Cavalcade Site, Houston, Texas.*

7 U.S. Environmental Protection Agency, March 1991. *South Cavalcade CERCLA RD/RA Consent Decree, Civil Action No. H-90-2406.*

8 Bechtel Environmental, Inc., March 1992. *Remedial Design Work Plan, South Cavalcade Site, Houston, Texas.*

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Pilot study tasks conducted to support the groundwater remedial design included a groundwater collection well pilot study, groundwater recovery trench pilot study and groundwater treatment system pilot study. Pilot study tasks were completed in October 1993. The *100% Remedial Design for the Groundwater Collection and Reinjection System and DNAPL Recovery System*[9] was submitted to EPA in December 1994 and was subsequently approved. The groundwater remedial design provided for groundwater collection and DNAPL recovery in three separate Site areas, referred to as Groundwater Remedial Action Areas (GRAAs), as shown on Figure 3.

Implementation of the groundwater remedial action was initiated in June 1995 in accordance with the EPA-approved *Remedial Action Work Plan* (RAWP)[10] dated May 1995 and associated support documents. The locations of the groundwater collection wells, DNAPL recovery wells, and combined groundwater collection/DNAPL recovery wells installed as part of the groundwater remedial action are also shown on Figure 3. One DNAPL recovery well (Well RWN-4) and four groundwater collection wells (RWN-1, RWN-2, RWN-3 and RWN-5) were installed within GRAA 1 located in the northern section of the Site. One DNAPL recovery well (Well RWS-5) and three groundwater collection wells (RWS-3, RWS-4, and RWS-6) were installed within GRAA 2 which includes the area formerly occupied by the coal tar distillation plant. Two combined groundwater collection/DNAPL recovery wells (RWS-1 and RWS-2) were installed within GRAA 3 which includes the area formerly occupied by the wood treating process area.

Following completion of the groundwater treatment plant modifications, start-up of the groundwater collection and DNAPL recovery components of the groundwater remedy was conducted in September 1995. In an EPA letter dated October 6, 1995[11], EPA indicated that "there is some question as to whether EPA will continue to apply the current remedial action goals [i.e., the remedial goals specified in the ROD issued in 1988] to groundwater cleanup." This direction was taken in response to the previously discussed July 31, 1995 EPA memorandum directing a policy

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9 McLaren/Hart Environmental Engineering Corporation, December 1994. *100% Remedial Design for the Groundwater Collection and Reinjection System and Dense Non-Aqueous Phase Liquid Recovery System, South Cavalcade Superfund Site, Houston, Texas*

10 Dames and Moore, May 1995. *Final Remedial Action Work Plan, South Cavalcade Site, Houston, Texas.*

11 U.S. Environmental Protection Agency, October 6, 1995. *South Cavalcade Street Superfund Site Groundwater Exposure Assessment Work Plan, September 1996, EPA Review Comments.*

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favoring ARAR waivers at Sites where it is technically impracticable to remediate groundwater to Federal or State standards. As provided by the October 6, 1995 EPA letter and in accordance with an agreement between EPA and Beazer, groundwater collection and treatment has been delayed pending determination of the potential inapplicability of the groundwater remedial goals specified in the ROD. Operation of the DNAPL recovery component of the groundwater remedy is currently ongoing.

DNAPL recovery operations were conducted in conjunction with groundwater pumping during November and December 1995 as start-up/shakedown of the groundwater treated system was completed. In January 1996, operation of the DNAPL recovery system in the passive mode of operation was initiated in accordance with the EPA-approved 100% Remedial Design. Evaluation of the DNAPL recovery data collected through June 1996 in accordance with the statistical protocol (i.e., zero-slope analysis) specified in the *Groundwater Extraction System Performance Monitoring Plan* (GESPMP)[12] indicated that DNAPL had been recovered to the "maximum extent possible" under the passive mode of operation.

As a result and in accordance with the EPA-approved 100% Remedial Design, DNAPL recovery with groundwater extraction to enhance hydraulic gradients was initiated in one GRAA (GRAA 3) to evaluate the effectiveness and practicability of this enhancement prior to its use in the other GRAAs. Evaluation of the DNAPL recovery data collected in GRAA 3 from July through September 1996 indicated that groundwater extraction (at a pumping rate of 0.3 gpm from individual recovery wells) appeared to enhance DNAPL recovery in Wells RWS-1 and RWS-2. Based on this observation, DNAPL recovery with groundwater extraction to enhance hydraulic gradients was initiated in GRAAs 1 and 2 in October 1996. Currently, DNAPL recovery with groundwater extraction is being conducted in all three GRAAs. As of the end of 1996, approximately 475 gallons of DNAPL have been removed from the shallow water bearing zone.

In addition to the ongoing DNAPL recovery operation, Beazer has been conducting annual groundwater monitoring since March 1993 in two deeper monitoring wells located in the vicinity of the Site, as stipulated in the ROD.

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[12] KEY Environmental, Inc., August 1995. *Groundwater Extraction System Performance Monitoring Plan, South Cavalcade Superfund Site, Houston, Texas.*

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Over the course if these investigative and remedial activities, several monitoring wells have been installed at the Site. Table 2 summarizes monitoring well construction information for these wells. This information is presented in order to facilitate the evaluation of groundwater information.

2.1.3 Shallow Site Geology

The majority of Site geologic information was developed during the RI and subsequent pilot testing and remedial activities. Shallow Site stratigraphy is depicted on geologic cross-sections A-A' and B-B' presented as Figures 4 and 5, respectively (See Figure 2 for the plan locations of the cross-section lines). The Site is underlain by a series of fluvial deltaic deposits consisting of continuous and discontinuous, interbedded layers of fine sand, silt and clay. Generalized descriptions of discrete geologic units in order of increasing depth from ground surface are provided below. In the descriptions provided below, reference is made to terminology used in the ROD, RI Report and subsequent documents.

The surficial geologic unit at the Site consists of deltaic deposits comprising the lower portion of the Beaumont Formation. This typically occupies an interval from ground surface to 17 to 22 feet below ground surface. These strata have been collectively referred to as Unit 1 in the RI Report. Approximately, the upper 8 to 12 feet of this unit is comprised of sandy or silty clay deposits. This upper zone within Unit 1 is referred to as the "shallow aquitard" in the RI Report. This unit is laterally continuous across the Site. According to the RI Report, this unit, in conjunction with the concrete or asphalt pavement, where present, permit relatively little recharge to shallow groundwater from surface water infiltration.

Below the surficial clay stratum is a zone of non-cohesive silty sand deposits, which are continuous across the Site. According to the RI Report, the thickness of this unit ranges from 2 to 15 feet across the Site. This zone is referred to as the "shallow aquifer" in the RI Report. Because this unit is laterally continuous, situated near to the ground surface and is generally comprised of a greater percentage of sandy material with respect to the other shallow geologic units beneath the Site, this unit is identified as the zone in which lateral movement of groundwater is most likely to occur. This zone is the subject of the fate and transport evaluation presented in this report.

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Directly underlying the shallow aquifer are interbedded deposits primarily composed of silts and clays of fluvial/deltaic origin. These deposits are laterally continuous across the Site and typically extend to a depth of approximately 115 feet below ground surface as shown on Figures 4 and 5. These sediments represent the strata referred to as Units 2 and 3 and the "intermediate aquitard" in the RI Report. The upper zone of cohesive silts and clays within Unit 2 has been referred to as the "the basal confining unit for the shallow aquifer" in previous documents.

The configuration of the upper surface of the intermediate aquitard (i.e., basal confining unit for the shallow aquifer) is depicted on Figure 6. The top of this unit is irregular and generally slopes from west to east in the opposite direction of shallow groundwater flow. The average vertical permeability of the intermediate aquitard is reported to be 3×10^{-8} cm/sec, which is indicative of an effective aquitard. Secondary features such as "slickensides" and sandy or silty seams were noted within the upper portion of this unit in some instances during the RI soil boring or monitoring well drilling activities. During the RI, soil samples were collected from within this aquitard for field screening for total aromatic hydrocarbons and for laboratory analysis for PAHs. The results of the screening and laboratory analyses do not indicate that DNAPL has migrated to depth within this unit via the naturally occurring secondary permeability features.

As indicated in the RI Report and shown on the geologic cross-sections A-A' and B-B', discontinuous zones of silty sand deposits exist within the intermediate aquitard at some locations. These discontinuous silty sand sediments comprise the lowermost portion of Unit 2 and are also referred to as the "intermediate zone" in the 100% Remedial Design. Groundwater monitoring wells were installed within this unit as part of the RI. Where present, the thickness of the discontinuous silty sand deposits are reported to range from 5 to 15 feet. In the areas of interest for this fate and transport evaluation (i.e., areas where DNAPL exists in the shallow aquifer), the base of the shallow aquifer and the top of the discontinuous silty sand unit are separated by a minimum vertical distance of 20 feet.

Strata in the interval from directly beneath the discontinuous silty sand deposits to an approximate depth of 115 feet below ground surface are comprised primarily of clay. These strata are referred to as Unit 3 in the RI Report. This unit acts as a basal confining unit for the overlying discontinuous silty sand deposits, where present.

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2.1.4 Hydrogeologic Conditions

Characterization of Site hydrogeologic conditions has been completed through implementation of RI and pilot testing activities. Aquifer characterization activities have focused primarily on the shallow aquifer and discontinuous silty sand unit within the intermediate aquitard. Table 2 presents monitoring well construction information which is of use to aquifer characterization.

Groundwater flow in the shallow aquifer is to the west. Observed horizontal hydraulic gradients range from 0.002 ft/ft to 0.006 ft/ft in the Northern Area and 0.003 to 0.006 ft/ft in the Southern Area (Keystone, July 1988). A potentiometric surface contour map for the shallow aquifer constructed from elevation data presented in the RI Report is included as Figure 7. Hydraulic conductivities have been determined through the completion of aquifer testing programs conducted in the southern and northern portions of the Site. An average hydraulic conductivity of 7.8×10^{-3} cm/sec (8,070 ft/year) for the shallow aquifer in the northern portion of the Site (i.e., GRAA 1) was determined from data obtained from a constant rate pumping test performed during the Groundwater Collection Trench Pilot Study[13]. An average hydraulic conductivity value of 1.6×10^{-3} cm/sec (1,655 ft/year) was calculated for the shallow aquifer in the southwestern portion of the Site (i.e., GRAA 3) from data obtained through a constant rate pumping test performed as part of the Extraction Well Pilot Study.

Average hydraulic conductivities for the discontinuous silty sand unit within the intermediate aquitard in the northern (i.e., GRAA 1) and southwestern (i.e., GRAA 3) portions of the Site were estimated as 3.9×10^{-4} cm/sec (404 ft/year) and 3.2×10^{-4} cm/sec (331 ft/year) respectively. These data were obtained from constant rate pumping tests conducted as part of the Extraction Well Pilot Study[14]. These estimated average hydraulic conductivity values for the discontinuous silty sand zone within the intermediate aquitard are approximately one order of magnitude less than the hydraulic conductivities estimated for the shallow aquifer.

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13 McLaren/Hart Environmental Engineering Corporation, October 1993. *Groundwater Collection Trench Pilot Study Report.*

14 Keystone Environmental Resources, Inc., July 1992. *Extraction Well Pilot Study Report, South Cavalcade Site, Houston, Texas.*

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Due to the lower hydraulic conductivity and lateral discontinuity of this unit, dissolved constituents in groundwater are expected to migrate within the intermediate water-bearing zone at a much slower rate in comparison to the shallow aquifer. Therefore, a groundwater fate and transport evaluation, which considers the potential lateral transport of constituents in the shallow aquifer, will be more protective than a similar assessment conducted for the discontinuous silty sand zone intermediate aquitard.

Evaluation of potentiometric surface elevations measured in monitoring wells screened within the shallow aquifer and discontinuous silty sand unit within the intermediate aquitard indicate that a downward vertical gradient exists within the shallow groundwater units beneath the Site.

2.1.5 Inferred Extent of DNAPL

An evaluation of the extent of DNAPL in the shallow aquifer was performed as part of the Remedial Design for the Groundwater Collection and Reinjection System and DNAPL Recovery System. This delineation of the extent of DNAPL was developed based on detailed evaluation of the following information obtained from the RI Report and subsequent pilot tests:

- The observed presence of a separate phase DNAPL layer in Site monitoring wells;
- The results of chemical analysis of soil and groundwater samples collected within the shallow aquifer;
- The location of the former plant process areas where the maximum past-release potential exists; and,
- The configuration of the top of the aquitard to the shallow aquifer.

This approach for assessing the possible presence of DNAPL is consistent with that described in the EPA document titled *DNAPL Site Evaluation*[15] by Mercer and Cohen.

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[15] Mercer, J.W., and R.M. Cohen, February 1993. *DNAPL Site Evaluation,* Robert S. Kerr Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Ada, Oklahoma.

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2.1.5.1 DNAPL Measurements and Constituent Concentrations in Groundwater

Evaluation of the presence of DNAPL in Site monitoring wells installed within the shallow aquifer and discontinuous silty sand zone within the intermediate aquitard was conducted during the RI and in conjunction with the Groundwater Collection Trench Pilot Test. During the RI, the presence of DNAPL in Site monitoring wells was based on visual observations made during collection of groundwater sampling. Determination of the presence or absence of DNAPL based on direct measurement using an oil/water interface probe was not conducted during the RI.

According to the RI Report, DNAPL was visually noted in shallow monitoring well OW-11 (located in the former coal tar distillation plant area) and monitoring wells MW-14 (located in the former wood treating process area) and P-03 (located in the former coal tar distillation plant area) which are installed in the discontinuous silty sand zone within the intermediate aquitard. Additionally, an evaluation of the RI groundwater analytical results suggests the possible presence of DNAPL in a limited number of groundwater samples collected from other monitoring wells. These data indicate that measured concentrations of some PAH constituents exceed their respective calculated effective solubilities in groundwater samples collected from shallow aquifer monitoring wells MW-06 (located in the former wood treating process area), OW-02 (located in the northern portion of the site in the vicinity of the former "Pond Area") and OW-10 (located in the former wood treating process area).

The absence or presence of DNAPL in Site monitoring wells was reevaluated during the Groundwater Collection Trench Pilot Study in August 1993 using an oil/water interface probe. If DNAPL was determined to be present in a monitoring well, then the apparent thickness of the DNAPL layer in the monitoring well was measured. Table 3 summarizes the results of this evaluation for those monitoring wells for which potential DNAPL presence was previously inferred based on RI groundwater analytical data and/or visual observations made during the RI.

As described in the *Groundwater Collection Trench Pilot Study Report Addendum* [16] (McLaren/Hart, 1993) and discussed during the December 15, 1993 pre-design meeting, the measured DNAPL

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[16] McLaren/Hart Environmental Engineering Corporation, 1993. *Groundwater Collection Trench Pilot Study Report Addendum, South Cavalcade Superfund Site, Houston, Texas.*

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thicknesses represent an overestimate of the actual DNAPL thickness in the aquifer. The conclusion, that DNAPL thicknesses measured in the monitoring wells provide an overestimate of the actual thickness in the aquifer, is predicated on the fact that these well screens and coarse sand backfill were extended below the top of a low permeability unit, which acts as a capillary barrier to vertical DNAPL migration. When a monitoring well is constructed in this manner, DNAPL may migrate vertically through the coarser backfill material surrounding the well screen. As a result, DNAPL will accumulate in the wellbore at elevations below the top of the low permeability barrier. In this instance, the measured DNAPL thickness will exceed the actual thickness in the aquifer by the length that the well extends beneath the top of the low permeability barrier. For example, review of the well construction and boring logs contained in the RI Report for wells OW-2 and MW-06 indicate that the bottom of the well is at an elevation of approximately one foot below the top of the clay unit.

The locations where DNAPL was noted in the discontinuous sandy silt zone within the intermediate aquitard (monitoring wells P-02, P-03, MW-12 and MW-14) correspond to locations where DNAPL was also observed in the shallow aquifer during either the RI or Groundwater Collection Trench Pilot Study. However, based on review of drilling and well construction techniques used for installation of the intermediate zone monitoring wells and subsurface geology (*i.e.*, presence of a low permeability semi-confining layer), it is believed that the DNAPL observed in the intermediate zone may have been carried down from the shallow zone during RI drilling activities. This is supported by the following information:

- The boreholes for intermediate well installations were advanced using the hollow stem auger drilling techniques. Surface casings were not installed to seal off the shallow zone and prevent downward migration of DNAPL during drilling and well installation activities. With the hollow stem auger drilling technique, no fluids are added or recirculated during borehole advancement. Thus, there are no fluids traveling in the borehole with an upward velocity while the boring is advanced. As a result, DNAPL could enter the borehole within the shallow zone and migrate, unimpeded and under the force of gravity, into the intermediate zone.

- Well construction details indicate that a bentonite pellet seal was not placed above the well screen in well P-02 and P-03. Thus, any openings between the cement-bentonite grout

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column and the borehole wall would act as a conduit for downward migration of DNAPL from the shallow aquifer to the intermediate zone.

2.1.5.2 Remedial Investigation Soil Analytical Data

Several soil borings were advanced within the shallow aquifer and discontinuous silty sand unit within the intermediate aquitard during the RI. Figure 8 presents the locations of these soil borings. Selected soil samples collected from within these units were screened in the field for total aromatic hydrocarbons using a fluorescence technique and/or analyzed in the laboratory for PAHs. The results of this testing are presented in Table 4.

This information was evaluated during the Remedial Design to assess the possible presence or absence of DNAPL where this determination cannot be made through direct observation i.e., locations where monitoring wells have not been installed. The two criteria used for potential DNAPL presence at a particular boring location was a total aromatic hydrocarbon concentration of greater than 10,000 mg/kg (1% of the soil mass) and/or a total PAH concentration of greater than 1,000 mg/kg (0.1% of the soil mass). These criteria are consistent with suggested methods for inferring the presence of DNAPL by interpreting chemical analysis as described in Mercer and Cohen (Footnote No. 15).

The borings meeting the above-stated criteria for inferring the possible presence of DNAPL are located either within the former wood treating process area or the former "Pond Area" in the northern portion of the Site as shown on Figure 9. With the exception of boring A10-SB01, where a total PAH concentration of 1416 mg/kg was measured in a soil sample collected from the intermediate zone, the constituent concentrations measured in the soil samples collected from the discontinuous silty sand unit within the intermediate aquitard do not exceed the criteria for inferring the possible presence of DNAPL. Thus, these results indicate that the vertical extent of DNAPL is limited to the shallow aquifer. As indicated previously in Section 2.1.5.1, surface casings were not installed to seal off the shallow zone and prevent downward migration of DNAPL during RI drilling activities. Information presented in the log for this boring (Volume 2, Appendix F of the RI Report [Reference No. 4]) suggests the presence of DNAPL in the shallow zone at this location. Thus it is possible that the total PAH concentration measured in the soil sample from boring A10-SB01 is not representative of conditions in the intermediate zone.

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2.1.5.3 Locations of Former Plant Process Areas

The locations of the former process areas were considered in the evaluation to delineate potential DNAPL recovery areas. The locations of the former wood treating area, the former coal tar distillation area and the former "Pond Area" are also depicted in Figure 9. The locations of the wood treating and coal tar distillation process areas were determined from Sanborn Maps and/or aerial photography presented in the RI Report. Additionally, DNAPL has been observed in the location of the former "Pond Area" located in the northern area of the Site. The location of this feature was determined through examination of a 1964 aerial photograph presented in the RI Report.

2.1.5.4 Confining Unit Configuration

The configuration of the clay unit underlying the shallow aquifer was considered in the delineation of the areas where DNAPL may be potentially present in the shallow zone. Because DNAPL movement in the subsurface is primarily controlled by gravity, the presence of low capillary barriers such as this clay unit serve to impede the downward migration of DNAPL. Subsequent lateral movement of DNAPL, if any, would be influenced by the slope of the capillary barrier. For example, lateral DNAPL movement to the west of the former wood treating area is unlikely, even though groundwater flow in the shallow aquifer is in this direction, because the upper surface of the clay confining unit slopes to the east. The slope of this confining layer is depicted in Figure 6. Additionally, low lying areas in the upper surface of a capillary barrier act as stratigraphic traps which limit the lateral migration of DNAPL. A trough in the basal confining unit, extending from the former wood treating operations area in the southwest corner of the site to the former coal tar distillation area along the southeast property boundary, was identified. The location of this trough roughly corresponds to monitoring well locations (MW-06, OW-10, and OW-11) where DNAPLs have been observed. A smaller and less pronounced depression in the confining layer also exists in the vicinity of the former pond area in the northern portion of the Site. The locations of these low-lying areas in the basal confining unit, in conjunction with the former locations of the plant process areas and direct measurements of DNAPL in the shallow aquifer, served as the basis for the placement of the DNAPL recovery wells.

Beazer believes that the creosote DNAPL observed at the Site is immobile based on the following information.

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- Any potential for future release of DNAPL to the subsurface was eliminated through plant closure approximately 34 years ago. Thus, it can be reasonably assumed that any DNAPL released during the plant operational period has achieved a static distribution as residual pools and lenses in the subsurface because the driving force for its continued migration (i.e. the continued release of DNAPL at the source) has been eliminated. This steady state condition will persist unless certain types of changes, such as a substantial increase in hydraulic gradients induced by groundwater pumping within the area where the DNAPL exists, are imposed on the hydrogeologic regime.

- The movement of DNAPL in the subsurface will be controlled by gravity and the slope of low-permeability stratigraphic units as opposed to groundwater flow. Lateral migration of DNAPL will therefore be in the down dip direction of any low permeability layers capable of halting the vertical migration of DNAPL. The upper surface of the basal confining layer for the shallow aquifer slopes to the east. Groundwater flow in the shallow aquifer is to the west. Because the basal confining layer for the shallow aquifer slopes in the opposite direction of groundwater flow, migration of free phase DNAPL in the direction of groundwater flow is very unlikely.

- The specific gravity of creosote is only slightly greater than water. Mercer and Cohen report that the specific gravity of creosote is typically in the range from 1.01 to 1.05 grams per cubic centimeter (g/cc), but may be as great as 1.14 g/cc in certain blends. Assuming other factors are equal, the relatively low density of creosote translates to lower lateral and vertical mobility of the free-phase liquid in comparison to other DNAPLs with greater specific gravities (e.g. chlorinated solvents) . Consequently, greater DNAPL pool heights are needed for lower density DNAPLs, such as creosote or other coal tar-based DNAPLs, to overcome capillary threshold entry pressures which act to resist DNAPL migration. Once a capillary barrier, such as a silt or clay layer, is encountered, which prohibits vertical migration of DNAPL, lower density DNAPLs, such as creosote, are less likely to migrate laterally. Furthermore, a greater dip angle on the capillary barrier would be required to allow for lateral movement of the lower density DNAPLs. The density of the creosote DNAPL at the South

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Cavalcade Site has not been measured. However, Beazer has measured a specific gravity of 1.05 g/cc for a creosote DNAPL collected from another similar wood treating site[17].

- Creosote solutions are much more viscous than water. Mercer and Cohen report viscosities for creosote and coal tar ranging from 10 to 70 centipoise (The viscosity of water is 1 centipoise). Thus, potentially mobile creosote would migrate at a much slower rate than water. The viscosity of creosote in the subsurface may become even greater over time as lighter more soluble fractions of the creosote solution dissolve in the groundwater. The viscosity of the creosote DNAPL at the Site has not been measured. However, Beazer has measured a viscosity of 18 centipoise for a creosote DNAPL collected from the former Nashua, New Hampshire Wood Treating Site (Footnote No. 17).

2.1.6 Groundwater Constituents of Interest

The COIs for this assessment are the primary components of creosote which include polynuclear aromatic hydrocarbon (PAH) compounds and aromatic volatile organic compounds (VOCs). PAH compounds are the predominant components of creosote solutions, typically comprising over 85% of the mass fraction[18]. The VOCs of interest for the South Cavalcade Site include benzene, toluene, ethylbenzene and xylene (BTEX).

In general, PAH compounds are characterized by low aqueous solubilities, moderate degradability, and a high affinity for adsorption to organic carbon. In general, the aqueous solubilities and degradation rates for these constituents are inversely proportional to the molecular weight of the compound. Adsorption to organic carbon increases with increasing molecular weight. Therefore, the higher molecular weight PAH compounds are typically less mobile in groundwater than the lower molecular weight PAHs.

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17 Queen's University, Department of Civil Engineering, December 1993. Laboratory Results of Creosote Testing for the Former Koppers Wood Treating Facility, Nashua, New Hampshire.

18 Mueller, J.G., P.J. Chapman and P.H. Pritchard. 1989. *Creosote-Contaminated Sites-Their Potential for Bioremediation.* Environmental Science and Technology, 23:1197-1201.

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The majority of the PAH mass fraction of creosote solutions is typically comprised of the more soluble and biodegradable lower molecular weight PAH constituents such as naphthalene and phenanthrene (Footnote No. 18). Thus, the majority of the mass within dissolved phase groundwater plumes created from a creosote source is typically comprised of the lower molecular weight PAH compounds such as naphthalene and phenanthrene.

The concentration of dissolved constituents in groundwater in equilibrium with a non-aqueous phase liquid (NAPL) comprised of a mixture of organic compounds, such as creosote, is termed the effective solubility. The effective solubility is defined as the mole fraction of a particular component in a chemical mixture multiplied by the aqueous solubility of the pure compound. The individual VOC compounds, in their pure form, are typically more soluble in water than the PAHs. However, because VOCs comprise a very small portion of the mass in creosote solutions (less than 0.1%), the effective solubilities of these constituents in groundwater in equilibrium with creosote are much less than their true aqueous solubilities. Therefore, dissolved concentrations of BTEX in groundwater at creosote sites are typically on the order of 1 milligram/liter (mg/l)[19].

2.1.7 Groundwater Quality

Site groundwater quality was characterized through two site-wide rounds of sampling and analysis completed during the RI and one supplemental groundwater sampling event completed in November 1993. These analytical results were compared to remedial goals specified in the ROD during the Remedial Design to define the areas to be addressed by the hydraulic containment component of the groundwater remedy. A tabulated summary of the RI groundwater analytical data is presented in Appendix A.

The supplemental groundwater sampling event completed in November 1993 involved the analysis of groundwater samples from on-site shallow aquifer monitoring wells located hydraulically downgradient of locations where DNAPLs have been observed. Additionally, groundwater samples were collected from the shallow aquifer monitoring wells where DNAPL has been observed to provide groundwater analytical data to support the development of groundwater treatment system modifications. Analytical data from the November 1993 groundwater sampling event is summarized

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[19] Kiilerich, O. and E. Arvin, 1996. *Groundwater Contamination from Creosote Sites*, Groundwater Monitoring & Remediation, Volume 16, No. 1, pp112-117.

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in Table 5. Table 6 summarizes the results of analyses for BTEX compounds in the Former Mobil Terminal Monitoring Well MW-17, which is located downgradient (west) of the southern area of the Site. A brief discussion of the distribution of COIs in shallow groundwater is provided below.

- Concentrations of one or more of the BTEX compounds above remedial goals were measured in the groundwater samples from the monitoring wells where DNAPL was noted, Benzene was the only BTEX compound measured at a concentration above its remedial goal in groundwater samples collected from monitoring wells located downgradient of the former coal tar distillation area (monitoring well MW-04) and the former "pond area" in the northern section of the Site (monitoring well MW-01).

- Information obtained from the TNRCC files indicates that Mobil has collected groundwater samples for analysis from monitoring well MW-17 on several occasions. Results of these analyses indicate concentrations of BTEX constituents below detection limits in all instances.

- One or more potentially carcinogenic polynuclear aromatic hydrocarbon (pcPAH) compounds were reported at estimated concentrations greater than the sample detection limits in groundwater samples from the monitoring wells where DNAPL was noted. The pcPAH constituents were not detected in groundwater samples collected from monitoring wells located downgradient of these areas.

- Analytical results from the supplemental groundwater sampling completed in November 1993 and samples collected from the pilot scale groundwater collection trench indicate that total concentrations of the metals of interest are less than remedial goals with two exceptions. Arsenic was measured at a concentration above the remedial goal in monitoring well MW-06 which is located in the former wood treating operations area. Zinc concentrations above the remedial goal were measured in the samples collected from the pilot groundwater collection trench. Concentrations of these constituents were less than remedial goals in on-site monitoring wells located hydraulically downgradient of these two locations. Additionally, arsenic and zinc concentrations measured in the groundwater samples collected from the background monitoring well (monitoring well MW-07) during the RI exceed their respective remedial goals. Because concentrations of inorganic constituents do not exceed the ROD remedial goals at the downgradient Site boundary and certain inorganic constituents were

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measured in the background groundwater samples analyzed during the RI, these constituents were not evaluated as part of this fate and transport evaluation in accordance with the EPA-approved Work Plan (Reference No. 1, Page 5-1).

- Concentrations of the organic and inorganic constituents are less than remedial goals in shallow aquifer monitoring wells MW-05 and MW-08 which are located to the west (downgradient) of the northern and southern sections of the Site, respectively.

The distributions of two of the more mobile and prevalent COIs in the shallow aquifer, naphthalene and benzene, are presented in Figures 10 and 11, respectively.

2.1.8 Local Groundwater Usage

As indicated in the ROD, there are no groundwater supply wells in the shallow aquifer within one mile of the Site. According to the ROD, on-Site businesses, and nearby businesses and residents, are all currently served by the city water supply which originates from either a deep well located more than ten miles from the Site or from a reservoir located more than 20 miles from the Site. Future water use is expected to be consistent with the current use. As part of this assessment, a well inventory was conducted to update and confirm the information presented in the ROD.

The well inventory consisted of a search of information on file with the Texas Water Development Board and the Harris-Galveston Coastal Subsidence District (HGCSD). Groundwater supply wells identified through this search are presented on Figure 12. The results of the recent evaluation are consistent with information presented in the ROD (page 14) in that no groundwater supply wells were identified in the shallow aquifer within a one-mile radius of the Site. With the exception of two wells, all identified wells are completed at depths of three hundred feet or more below ground surface. The remaining two wells are reportedly completed at depths of 61 and 80 feet below ground surface, are not located hydraulically downgradient of the Site, and are located approximately 2000 feet from the Site boundary.

As stipulated in the ROD, Beazer currently conducts annual groundwater monitoring in two deeper monitoring wells installed to the southwest of the Site. The two monitoring wells, designated as LCW-01 and DW-02, are completed at depths of 530 feet and 225 feet below ground surface,

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respectively. Groundwater samples are analyzed for the pcPAHs by EPA Method 8310. Analysis by this method provides for detection limits for the individual constituents of interest ranging from 0.02 ug/l to 0.15 ug/l. Five sampling events have been completed to date. Analytical results for the pcPAH constituents have been less than their respective detection limits for all five sampling events. These groundwater analytical results demonstrate that no impact to the deeper aquifers beneath the Site currently exists.

The potential for future use of groundwater from the shallow aquifer in the vicinity of the Site is extremely remote. As indicated in the ROD (Page 13), on-Site occupants and neighbors are all served by the City water supply which originates from either a deep well located more than 10 miles off-site or a reservoir located over 20 miles from the Site. On-Site property owners are prohibited from installing groundwater production wells on their properties by virtue of their respective Consent Orders with the United States and corresponding settlement/access agreements with Beazer. The permitting process established by the HGCSD serves to restrict future groundwater usage in the Houston area. The role of the HGCSD is to regulate groundwater withdrawals for the purpose of ending subsidence which causes flooding. Reportedly, as much as 10 feet of subsidence has occurred in parts of Harris County.

Beazer has determined that the HGCSD is not likely to grant permits for new groundwater wells in the Harris County area, and particularly not for any wells that would draw from the shallow aquifer underlying the Site and the surrounding area. The HGCSD restricts by rule installation of new groundwater wells in Harris County, Texas. Specifically, the District requires persons to submit a permit application and to obtain a permit before installing a new well within its jurisdiction. Once submitted, the District will conduct a hearing on the permit application to determine whether to grant the permit. In so doing, the District will consider, among other factors:

(1) The quality, quantity, and availability of surface water at prices competitive with that charged by suppliers of surface water in the district; and

(2) The applicant's use of water conservation measures.

The HGCSD may not grant the permit unless it first finds that there is "no adequate and available substitute or supplemental source of surface water at prices competitive with those charged by

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suppliers of surface water in the district" pursuant to §TWC at 151.126. The HGCSD considers surface water to be available "if it can be utilized with the exercise of reasonable diligence" (District Rule 5.2).

However, there are some exemptions regarding the HGCSD authority to restrict well drilling in Harris County. If a well is for domestic use, is less than 5-inches in diameter and serves only one house, an HGSCD permit is not required. For commercial applications HGCSD does not issue permits if the city provides water from a surface source; however, if the city uses groundwater for the area then the commercial applicant may be allowed to drill their own well as long as surface water use is not decreased. Both permitted and permit-exempt groundwater wells are required to be registered with the HGCSD at least five days prior to their installation.

Even if the District was to grant a new permit to a commercial applicant or a resident decided to install their own groundwater production well, groundwater wells in the vicinity of the South Cavalcade Site are typically installed within the deeper water bearing units.

Also the relatively "poor" natural groundwater quality in the shallow aquifer in the vicinity of the Site makes its use as a private water source extremely unlikely. Naturally occurring inorganic constituents, iron and manganese, were measured at levels well above their respective Texas Drinking Water Standards in groundwater samples during the RI and November 1993 supplemental groundwater sampling, respectively, demonstrating that the shallow groundwater is undesirable for future use due to natural conditions.

The information presented above indicates that future use of shallow groundwater in the vicinity of the Site is not probable, and therefore, exposure to any constituents which may migrate off-site, is extremely unlikely.

2.2 Conceptual Site Model

This section describes the conceptual site model by summarizing the critical parameters and/or mechanisms that would effect the transport and/or attenuation of COIs from potential source areas to potential receptors.

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The COIs are primarily limited to the groundwater within the shallow fluvial deltaic deposits, comprising intermittent, interbedded fine sand, silt, and clay up to a depth of approximately 22 ft-bgs. The unconfined aquifer within this unit is encountered at a few feet below the ground surface and flows in a generally westerly direction with a horizontal hydraulic gradient ranging from 0.002 to 0.006 ft/ft. Average horizontal hydraulic conductivities for the northern and southern sections of the Site are 7.8×10^{-3} cm/sec (8,070 ft/year) and 1.6×10^{-3} cm/sec (1,655 ft/year), respectively. Although a vertical hydraulic gradient exists between the shallow aquifer and the intermediate aquifer (60 to 115 ft-bgs), no COIs have been detected within the intermediate aquifer at a depth of 115 ft-bgs. For this reason, the unit of interest considered for this Conceptual Site Model, is the shallow aquifer.

Based on groundwater sampling within the shallow zone, the COIs have been identified to be BTEX and PAH compounds, which are typical for creosote DNAPL and are primarily limited to the shallow unconfined aquifer. The source area for these COIs are the areas at the site where DNAPL is determined to be present. Due to the DNAPL having achieved a static distribution within the shallow aquifer, no addition to or movement of DNAPL is anticipated over time. However, the areas containing static free-phase or residual DNAPL are anticipated to be a long term source for the occurrence of dissolved phase COIs within groundwater.

COIs dissolve within the groundwater as a function of the effective solubilities of the respective DNAPL components. These COIs flow in the general groundwater flow direction and migrate via dispersion and advection mechanisms. Attenuation mechanisms such as adsorption and biodegradation retard the rate at which the COIs migrate within groundwater. PAHs exhibit low aqueous solubilities and are readily attenuated by naturally occurring organic carbon in the aquifer matrix. BTEX constituents exhibit moderate mobility, however, these constituents are more readily attenuated by biodegradation.

The nearest potential future off-site groundwater exposure points are approximately 400 feet from the potential constituent source areas. This distance and the hypothetical exposure point is used for the further development of the fate and transport model (discussed in Section 3.0). However, the availability of water from the public supply, poor quality of the shallow groundwater due to naturally occurring conditions, the low yield of the shallow aquifer, and the fact that there are no groundwater withdrawal wells (within the shallow aquifer) within one mile of the site, confirm the protective

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nature of the assumed 400 foot distance to the nearest possible future receptor. For this reason, a high level of safety and protectiveness is inherent within the fate and transport evaluation.

The poor quality of the shallow groundwater due to naturally occurring conditions is indicated by iron concentrations measured during the RI and manganese concentrations measured during the supplemental sampling event conducted in November 1993. The Secondary Maximum Contaminant Level (SMCL) for iron is 0.3 mg/l. Iron concentrations in shallow groundwater exceeded the SMCL in all shallow zone groundwater samples analyzed during the RI. The measured iron concentrations ranged from 1.42 to 181 mg/l.

The SMCL for manganese is 0.05 mg/l. During the November 1993 sampling event, manganese concentrations exceeded the SMCL in seven of the eight shallow monitoring wells sampled. Total manganese concentrations greater than the SMCL ranged from 0.14 mg/l to 3.3 mg/l.

Information generated through the pumping test completed by Keystone in the southwest area suggest that the shallow zone is capable of yielding only small quantities of groundwater to an extraction well. According to the Extraction Well Pilot Study Report (Reference No. 14), the shallow groundwater pumping well went dry after pumping for five hours at a rate of 1.0 gpm. After pumping at 0.5 gpm for 72 hours, a drawdown of 10.73 feet, which corresponded approximately with the bottom of the shallow zone, was measured in the pumping well.

The above-described Conceptual Site Model was used as the basis for the analytical modeling completed within the remainder of this document.

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3.0 ANALYTICAL MODELING APPROACH AND METHODOLOGIES

This section describes the technical approach and methodologies employed in completing the fate and transport evaluation of PAH and VOC constituents in shallow groundwater at the South Cavalcade Site. Justification for the selection of the analytical solutions used to simulate the fate and transport of dissolved constituents in groundwater is also presented. As necessary, the input parameters to the analytical solutions are presented and referenced.

Fate and transport simulations were performed for the COIs (PAHs and aromatic VOCs) identified in the EPA-approved Work Plan (Reference No. 1, Page 5-1). As indicated previously, the inorganic constituents of interest (arsenic, chromium, copper, lead and zinc) were not evaluated in this assessment because data from the RI indicate detectable levels of these constituents in groundwater samples collected upgradient of the Site, and the concentrations reported for these samples are comparable to those measured in on-Site groundwater samples. In addition, the more recent groundwater analytical data indicate that concentrations of these constituents are less than remedial goals at the downgradient Site boundaries.

The model simulations were performed in a focused step-wise manner. Initially, the analytical model simulations were completed to estimate the effects of only advection, dispersion and adsorption on future constituent concentrations in groundwater. These initial worst case simulations were served essentially as a screening tool in order to focus subsequent simulations on those constituents which indicated a future potential to migrate to distances beyond the hypothetical future exposure points at levels above their respective remedial goals. Based on the results of these initial "worst case" simulations, Beazer upgraded the analytical model and performed additional simulations to account for intrinsic biodegradation effects. This approach provides a protective estimation of the natural attenuation occurring, balancing completion of more aggressive modeling with the need to demonstrate the degree of natural attenuation.

3.1 Selection of Analytical Constituent Transport Models

In accordance with the EPA-approved Work Plan (Reference No. 1, Page 3-1), an initial "worst case" evaluation of the fate and transport of dissolved constituents in groundwater was performed through the use of a one-dimensional analytical model that simulates the dispersion of constituents

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in groundwater and subsequent attenuation, via adsorption to organic matter within the aquifer matrix, as a function of groundwater velocity, time, and distance from the potential constituent source. This assessment was completed using a modified form of the Ogata-Banks equation[20] which is a one-dimensional solution to the dispersion-advection equation. A one-dimensional solution was considered appropriate for the initial simulations to satisfy the objective of providing a "worst case" and most protective estimation of potential constituent transport. The Ogata-Banks equation was selected for these simulations because it is a referenced and peer-reviewed analytical solution and it is capable of simulating the fate and transport of dissolved constituents originating from a continuous source (i.e., non-aqueous phase liquid). A Microsoft Excel™ spreadsheet program was developed for conducting the Ogata-Banks simulations.

The Ogata-Banks equation assumes that a continuous source of dissolved phase constituents exists at a specific location (x) and that the concentrations of dissolved constituents at the downgradient limit of the source area (i.e, x=0) remains constant over time. Free-phase and residual DNAPL have been observed in the shallow aquifer in the southwest area of the Site (the former wood treating process area), southeast area (the former coal tar plant area) and in a small area in the northern portion of the Site (in the vicinity of DNAPL recovery well RWN-4). The rate of dissolution of the DNAPL into the shallow groundwater is limited by the relatively low effective solubilities of the DNAPL constituents and, to a lesser extent, by the relatively low groundwater flow velocities. Therefore, it is reasonable to assume for the purpose of the proposed simulations, that the free phase and/or residual DNAPL act as a continuous source for dissolved phase constituents. Based on this assumption, the Ogata-Banks equation is a valid analytical model for simulation of the fate and transport of dissolved constituents in groundwater over time.

As provided by the EPA-approved Work Plan (Reference No. 1, Page 3-1), Beazer completed additional simulations that consider the potential effects of intrinsic biodegradation. The analytical simulations considering the effects of intrinsic biodegradation were performed using the BIOSCREEN computer software program obtained through the EPA Center for Subsurface Modeling Support in Ada, Oklahoma. The BIOSCREEN model was selected for these simulations because this analytical model is predicated on the same boundary conditions and assumptions as the Ogata-Banks equation. The BIOSCREEN computer tool is capable of simulating intrinsic

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[20] Domenico, P.A. and F.W. Schwartz, 1990. *Physical and Chemical Hydrogeology*, John Wiley & Sons, New York, pp 640.

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biodegradation as a first order kinetic reaction (i.e., decay process). Similar to the modified Ogata-Banks equation, this simulation incorporates the effects of advection, dispersion, and retardation.

This simulation is based on the Domenico[21] "analytical model for multi-dimensional transport of a decaying contaminant species." The BIOSCREEN simulation can be considered to be the multidimensional analogue to the modified Ogata-Banks equation with the additional consideration of first order decay of the contaminant species. By assigning an infinite value to the half-life for the constituent source decay, this solution can be used to simulate the fate and transport of dissolved phase constituents from a DNAPL source. Therefore, the BIOSCREEN solution was determined to be appropriate for use in this fate and transport evaluation.

3.2 Analytical Solution Description

The modified Ogata-Banks equation accounts for one-dimensional dispersion in the direction of groundwater flow and retardation of groundwater constituents via adsorption to organic carbon in the aquifer materials. The modified form of the Ogata-Banks dispersion-adsorption equation is as follows:

$$C = \left(\frac{Co}{2}\right) erfc\left[\left(R_f x - v_{gw} t\right) / 2\sqrt{\left(\alpha_x v_{gw} t R_f\right)}\right]$$

where: C = constituent concentration at time (t) at distance (x) from the source area;

Co = constituent concentration at time t=0 at the downgradient limit of the source area (x=0);

R_f = the retardation factor for the constituent of interest;

v_{gw} = horizontal groundwater velocity; and,

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[21] Domenico, P.A., 1987. *An Analytical Model for Multi-Dimensional Transport of a Decaying Contaminant Species*. Journal of Hydrology, Vol. 91, pp 49-58.

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α_x = longitudinal dispersivity.

For this model, the constituent concentrations in groundwater at the downgradient limit of the source area will be assumed to be equal to their respective estimated effective solubilities in groundwater in equilibrium with creosote. As indicated in Section 2.1.5, the effective solubility is a function of the solubility of the pure compound in water and the mole fraction of the compound in the NAPL solution.

The effective solubility of a particular constituent can be estimated by the equation[22]:

$$S^e_i = X_i S_i$$

where:

S^e_i = the effective solubility or dissolved-phase concentration of compound i;
X_i = the mole fraction of compound i in the NAPL solution; and,
S_i = the solubility of pure compound i in water.

The horizontal groundwater velocity (v_{gw}) will be calculated using Darcy's Law[23] as given below:

$$v_{gw} = \frac{Ki}{n}$$

where: K = horizontal hydraulic conductivity;

i = horizontal hydraulic gradient; and,

n = effective porosity of the porous medium.

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22 Feenstra, S., 1990. *Evaluation of Multi-Component DNAPL Sources by Monitoring of Dissolved Phase Concentrations,* Presented at the Conference of Subsurface Contamination by Immiscible Fluids, International Association of Hydrogeologists, Calgary, Alberta, April 18-20, 1990.

23 Freeze, R.A. and J.A. Cherry, 1979. *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

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The retardation of constituent migration in groundwater via adsorption is directly proportional to the amount of naturally occurring organic carbon in the porous media. The equation for calculating the retardation factor (R_f) is as follows:

$$R_f = v_{gw}/v_c = 1 + K_p(\rho_b)/n$$

where: v_{gw} = horizontal groundwater velocity;

v_c = the velocity of the constituent of interest;

K_p = the partitioning coefficient;

ρ_b = the bulk density of the porous material; and,

n = effective porosity of the porous medium.

The equation for estimating the partitioning coefficient is as follows:

$$K_p = K_{oc} f_{oc}$$

where, K_{oc} = partition coefficient of the compound on organic carbon; and,

f_{oc} = fraction of organic carbon in the soil.

The BIOSCREEN solution was used to conduct fate and transport evaluations by simulating the effects of biodegradation as a first order kinetic reaction. As indicated previously, the BIOSCREEN simulation can be considered to be a multi-dimensional analogue to the modified Ogata-Banks equation with the additional consideration of first order decay (i.e., biodegradation) of the contaminant species. The BIOSCREEN solution is based on the Domenico analytical model for multi-dimensional (i.e., 3-D) transport of a decaying contaminant species:

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$$C(x,y,z,t) = (\frac{C_0}{8}) \exp[(x/2\alpha_x)\ [1 - (1 + 4\lambda\alpha_x/v)^{1/2}]]\ erfc[(x - vt(1 + 4\lambda\alpha_x/v)^{1/2})/(2(\alpha_x vt)^{1/2})]$$

$$[erf[(y + Y/2)/(2(\alpha_y x)^{1/2})] - erf[(y - Y/2)/(2(\alpha_y x)^{1/2})]]$$

$$[erf[(z + Z)/(2(\alpha_z x)^{1/2})] - erf[(z - Z)/(2(\alpha_z x)^{1/2})]]$$

BIOSCREEN simulations can be performed to incorporate dispersion in two or three dimensions. Considering dispersion in the longitudinal and transverse dimensions only, the Domenico "analytical model for multi-dimensional transport of a decaying contaminant species" reduces to the following equation (Reference No. 21, Page 647):

$$C(x,\ y,\ t) = (\frac{C_0}{4}) \exp[(x/2\alpha_x)\ [1 - (1 + 4\lambda\alpha_x/v)^{1/2}]]\ erfc[(x - vt(1 + 4\lambda\alpha_x/v)^{1/2})/(2(\alpha_x vt)^{1/2})]$$

$$[\ erf[(y + Y/2)/(2(\alpha_y x)^{1/2})] - erf[(y - Y/2)/(2(\alpha_y x)^{1/2})]]$$

where: λ = the decay constant, or 0.693 divided by the constituent half life;

Y = the source width measured perpendicular to the direction of groundwater flow;

α_y = transverse dispersivity;

The remaining variables in the above equation are as defined previously in the description of the Ogata-Banks Equation.

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The BIOSCREEN model was effectively transformed to a one-dimensional solution to provide a more protective evaluation of constituent fate and transport than a similar multi-dimensional simulation in terms of the simulated constituent migration distance. This was accomplished by entering a negligible value for transverse dispersion of $1x10^{-10}$ ft. The one-dimensional approach is considered most protective because this approach prevents decreases in constituent concentrations due to transverse and vertical dispersions. This transformation was also performed in order to be consistent with the one-dimensional Ogata-Banks simulations, and because the fate and transport evaluation is concerned more with downgradient constituent migration than with the potential lateral spreading of constituents via transverse dispersion.

3.3 Identification of Boundary Conditions and Input Data

The following subsections define the boundary conditions developed for the fate and transport evaluation and the parameter values used as input to the analytical solutions.

3.3.1 Boundary Conditions

The analytical simulations were performed to estimate concentrations of the COIs as a function of time and distance from the source. Development of the necessary initial boundary conditions required specification of the limits of the estimated constituent source areas (i.e., x = 0), COI concentrations at the downgradient limit of the source (Co) and the time at which the source concentrations first existed (t=0). The same boundary conditions were specified for the simulations using the Ogata-Banks equation and the BIOSCREEN analytical solution except that the use of BIOSCREEN requires determination of a source area width. The specified boundary conditions for Northern and Southern Areas are depicted on Figures 13 and 14, respectively, and are described below.

Source Concentrations (Co) - The assumed concentrations of the groundwater COIs at the downgradient limits of the constituent source (i.e., x = 0) will be values corresponding to the calculated effective solubilities of the respective constituents in groundwater in equilibrium

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with creosote, as reported by Feenstra and Cherry[24]. These values are summarized in Table 7. The source concentrations were assumed to remain constant over the time period that constituent fate and transport was modeled to appropriately simulate DNAPL acting as a source for dissolved phase constituents in groundwater.

Source Area Limits (x = 0) - The boundary condition (x = 0) was defined as the downgradient limit of the areas within GRAA 1 (northern area) and GRAA 3 (southwestern area) identified as "Potential DNAPL Recovery Areas" on Figure 15. Because GRAA 2 is located hydraulically upgradient of GRAA 3, the transport of COIs in shallow groundwater was not simulated for GRAA 2. The results of the fate and transport evaluations conducted for GRAA 3 can essentially be considered as an overly protective estimate of constituent transport from GRAA 2. As indicated previously, the limits of these areas were defined based on evaluation of the locations of former plant process area, groundwater and soil analytical data, direct observation of DNAPL in Site monitoring wells and configuration of the upper surface of the basal confining unit for the shallow aquifer. The source area width specified as a boundary condition for the BIOSCREEN analytical solution is the width of the respective "Potential DNAPL Recovery Areas" measured perpendicular to the groundwater flow direction.

Time at Which the Source Concentrations First Existed (t_0) - The time at which the source concentrations first existed (t_0) could be defined as any time between the date when wood treating operations were first conducted (*circa.* 1910) and the date when wood treating operations were discontinued (1962). To provide a worst case estimate of the distance that constituents may have migrated to date or a most protective estimate of the time when a constituent may reach a potential exposure point in the future, t_0 is defined as the date when wood treating operations were first conducted. This assumption that a "source" existed at the time that plant operations were initiated should be viewed as most protective because it is likely that any downward migration of constituents from the ground surface to the saturated zone would be significantly slowed by the low permeability clay which comprises the vadose zone soils.

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[24] Feenstra S. and J.A. Cherry, 1990. *Groundwater Contamination by Creosote*, In *Proceedings from The Eleventh Annual Meeting of the Canadian Wood Preserving Association*, Toronto, Ontario.

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For simulations which consider the effects of intrinsic biodegradation, t_0 was protectively assumed to be the date when wood treating operations were discontinued (1962). The assumption favors a "worst case" estimate of the time needed for a particular constituent needed to attain a steady state constituent distribution in groundwater because the time period during which biological activity has acted to reduce dissolved constituent concentrations would likely be underestimated. Note that if the time predicted by the worst case BIOSCREEN simulation for a particular constituent to attain a steady state distribution in groundwater is less than 35 years (i.e., 1962 to 1997), the distances that constituents are predicted to have migrated would be the same regardless of whether the source first existed in 1910 or 1962.

The boundary conditions for the distance over which the simulations were performed is the distance to the nearest non-industrial property downgradient of the Site. This boundary condition is most protective because, as discussed previously, future use of the shallow aquifer in the vicinity of the Site is highly unlikely. The selection of the nearest non-industrial property as the hypothetical location for future groundwater use, while protective, is justified on the basis that the well inventory completed by Beazer indicates that groundwater supply wells installed for industrial use are typically completed at depths of 300 feet or more (See Table on Figure 12). As indicated previously, on-Site occupants are prohibited from installing groundwater production wells on their properties by virtue of their respective Consent Orders with the United States and corresponding settlement/access agreements with Beazer. In the Northern Area, the area between the Site boundary and the hypothetical location of future groundwater use is occupied by a right-of-way for an active rail line. In the Southern Area, the area between the Site boundary and the hypothetical location of future groundwater use is occupied by an active petroleum storage facility and a right-of-way for an active rail line. The selection of the locations of the hypothetical future groundwater users as the nearest non-residential properties considers and is consistent with the exemption from HGCSD permitting for wells less than 5-inches in diameter and serving a single household.

The time period over which the fate and transport of the COIs were simulated using the Ogata-Banks equation corresponds to the time at which the simulations depict that the advective front has reached the hypothetical future receptor location. BIOSCREEN simulations were run to determine the time at which the simulated plume reached a "steady state" condition. The simulated "steady state" plume

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configurations represent estimated maximum constituent concentrations within the plume and the maximum distance that the constituents may migrate downgradient of the potential source area.

3.3.2 Input Data

To the extent practicable, Site-specific information was utilized as input to the groundwater constituent fate and transport models. In instances where it was not feasible to use Site-specific data for input to the models, default values from peer-reviewed published sources were used. These assumed parameter values were selected to be representative of Site conditions, to the extent practicable. Ranges of input parameter values were specified and utilized to develop "best case" and "worst case" scenario simulations. The range of parameter values used in these simulations and associated references are provided in Table 8. Rationale used in the selection of the input parameter values is presented below.

Hydraulic Conductivity - Site-specific hydraulic conductivity information was used as input data in the fate and transport simulations. Because the shallow aquifer is comprised of heterogeneous deltaic deposits, a range of hydraulic conductivity values from both the north and south areas of the Site was developed for use in the fate and transport evaluations.

The hydraulic conductivity values determined from the aquifer test performed by McLaren/Hart in 1993 using the pilot study collection trench in the northern portion of the Site (GRAA 1) were used as input to the fate and transport evaluations conducted for this portion of the Site. As part of this aquifer testing program, hydraulic conductivities were calculated from drawdown measurements taken in 14 monitoring wells or piezometers in the vicinity of the groundwater collection trench. Hydraulic conductivity values calculated from these data ranged from 7,200 ft/year to 38,000 ft/yr. According to the Groundwater Collection Trench Pilot Study Report, "the majority of transmissivity values ranged from 2,000 to 3,000 gallons per day per foot (gpd/ft)" Assuming a saturated thickness of 15 feet, the transmissivity value at the upper end of the typical range specified by McLaren/Hart (3,000 gpd/ft) corresponds to a hydraulic conductivity of 9,800 ft/yr. Therefore, the use of the maximum value for hydraulic conductivity estimated from the pilot groundwater collection trench aquifer test (38,000 gpd/ft) is considered most protective.

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Hydraulic conductivity values calculated from pumping tests performed by Keystone in the southwestern section of the Site (GRAA 3) were used as input to the fate and transport evaluations conducted for this portion of the Site. As part of this aquifer testing program, hydraulic conductivities were calculated from drawdown measurements taken in four monitoring wells or piezometers in the vicinity of the groundwater extraction well. Hydraulic conductivity values calculated from these data ranged from 675 ft/year to 2,600 ft/yr.

Hydraulic Gradients - A range of values for the horizontal hydraulic gradient, as determined through previous Site-wide level measurement events (from the RI or pilot study activities), was used to simulate potential groundwater constituent transport under non-pumping conditions. A hydraulic gradient of 0.006 ft/ft was used as input for the "worst case" simulations of constituent fate and transport under non-pumping conditions for both the north and south areas. Hydraulic gradients of 0.002 ft/ft and 0.003 ft/ft were used in the "best case" simulations of constituent fate and transport under non-pumping conditions for the northern and southern areas, respectively.

At the request of EPA, simulations were performed assuming future groundwater withdrawal from the shallow aquifer. The assumed scenario would represent a "worst case" estimate of potential constituent transport because the estimated hydraulic gradients under this hypothetical and unlikely scenario are significantly greater than those observed under non-pumping conditions. The increased hydraulic gradients assumed under this hypothetical "worst case" future scenario result in a linear increase in the estimated groundwater seepage velocity. Because of the availability of the public water supply, poor natural groundwater quality and restrictions placed on groundwater use by the HGCSD, it is unlikely that the shallow groundwater would be used in the future as a private source in the vicinity of the Site. Therefore, the results of this evaluation should be viewed as an extreme overestimate of the potential for exposure to constituents in groundwater.

The location of this hypothetical future groundwater withdrawal well was assumed to be at the nearest reasonable possible off-Site location at the area downgradient of the Site. This assumption regarding the location of possible future groundwater withdrawals is valid because future on-Site use of groundwater is prohibited by virtue of the Consent Orders

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between the on-Site property owners and the United States and corresponding settlement/access agreements with Beazer.

In calculating the hydraulic gradient under this worst case scenario, it was assumed that the groundwater level in the hypothetical groundwater extraction well corresponds to a drawdown equal to two-thirds of the saturated thickness of the aquifer. This assumption is based on the theory that it is impractical to pump a well in an unconfined aquifer at a drawdown that exceeds two-thirds of the saturated thickness of the water-bearing sediments[25] due to dewatering of the aquifer in the vicinity of the pumping well and the transition from laminar to turbulent flow conditions. This assumption favors a worst case estimate of constituent transport because well losses would likely preclude maintaining a pumping groundwater level in the well which would result in drawdown in the aquifer immediately adjacent to the well at an elevation corresponding to two-thirds of the saturated thickness of the shallow aquifer (i.e., it does not account for well efficiency). Also, it is unlikely that a private supply well in the shallow aquifer would be pumped in a continuous mode necessary to maintain the presumed increased hydraulic gradient.

Effective Porosity and Bulk Density- Assumed values for effective porosity and bulk density were obtained from the publication *Groundwater* by Freeze and Cherry. These values were selected to be representative for the type of geologic material (fine sand and silt) which comprises the shallow aquifer. A value of 37.5% was used for the effective porosity parameter, as this value represents an intermediate porosity value for the aquifer materials of interest. However, sensitivity analysis of the effective porosity parameter indicates that varying this parameter exerts a negligible effect on the modeling results.

Organic Carbon Partitioning Coefficient - Values for the organic carbon partitioning coefficients for the COIs have been determined experimentally by researchers. The U.S. EPA publication *Subsurface Remediation Guidance*[26] was used as the resource for this information for the COIs. Use of these published and experimentally determined values is

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25 Driscoll, F.G, 1989. *Groundwater and Wells, Second Edition,* Johnson Filtration Systems, Inc., St. Paul Minnesota, pp434.

26 U.S. EPA, 1990. *Subsurface Remediation Guidance,* EPA/540/2-90/011b.

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appropriate for this assessment because the organic carbon partitioning coefficient is a function of the chemical compound itself and is independent of Site conditions.

Fraction of Organic Carbon in Soil - Input values for the fraction of organic carbon in soil are those compiled by Karickhoff[27]. These values were selected to be representative of the types of geologic materials (fine sand and silt) observed within the shallow aquifer. The value for soil organic carbon content (0.0086) used in the worst case simulations of constituent transport is at the lower end of the range of typical values for sand reported by Karickhoff. Use of this value in this assessment should be considered protective because the shallow aquifer sediments contain a significant percentage of silt which typically have a higher percentage of organic carbon. Typical organic carbon contents for silts, as reported by Karickhoff, are one to two orders of magnitude greater than those reported for sand. The highest value for soil organic carbon content used in this assessment corresponds to upper end of the range of typical values for organic carbon content of sand.

Longitudinal and Transverse Dispersivity - A range of values for longitudinal dispersivity was obtained from literature. Gelhar, et al. reported that longitudinal dispersivity generally increases with scale[28]. For the concentration versus distance graphs developed for this assessment, the "scale" is considered as the distance from the downgradient limit of the potential source area to the hypothetical future off-site groundwater user (on the order of 400 feet).

For concentration versus time graphs, different values for longitudinal dispersivity were used for the distances (i.e., scale) represented by each of the three curves. Dispersivity values utilized in the worst case transport simulations were calculated using an algorithm developed

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27 Karickhoff, S.W., D.S. Brown, and T.A. Scott. 1979. *Sorption of Hydrophobic Pollutants of Natural Sediments*, Water Research, Vol. 13, pp 241-248.

28 Gelhar, L.W., *et al*, 1985. *A Review of Field-Scale Physical Solute Transport Processes in Saturated and Unsaturated Porous Media*, Electric Power Research Institute, Palo Alto, California.

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by Xu and Eckstein[29] based on their evaluation of Gelhar's work. For example, this algorithm calculates a dispersivity value of approximately 16 feet for a scale of 400 feet.

For the best case evaluations of constituent transport, a value one order of magnitude less than specified above was used (approximately, 1.6 feet). This value is within the low end of the range reported by Gelhar for the scale of this evaluation.

For the BIOSCREEN simulations, transverse dispersivity was protectively assumed to be negligible. BIOSCREEN evaluations were performed with the transverse dispersion term set at a value essentially equal to zero (10^{-10} ft) so that the BIOSCREEN output simulates constituent transport in only the longitudinal dimension. The molecular diffusion term included in the calculation of the longitudinal coefficient of hydrodynamic dispersion was assumed to be negligible.

Biodegradation Half-Lives - To provide a most protective prediction of constituent fate and transport and ensure that constituent concentrations and times needed for constituents to achieve a steady state distribution in shallow groundwater would not be underestimated, BIOSCREEN simulations were performed using input parameter values which favor predictions of the greatest constituent transport and the least reduction in constituent mass due to the effects of biodegradation. Biodegradation half-lives used as input in these simulations were the highest values in the ranges listed in the literature reference[30].

3.4 Analytical Model Simulations

The analytical simulations were completed in a step-wise manner. For each series of simulations, constituent transport in the northern section of the Site (GRAA 1) and the southern section of the Site (GRAA 3) were evaluated separately. As indicated previously, because GRAA 2 is located hydraulically upgradient of GRAA 3, the transport of COIs in shallow groundwater was not

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29 Xu, Moujin and Y. Eckstein, 1995. *Use of Weighted Least-Squares Method in the Evaluation of the Relationship Between Dispersivity and Scale*, Journal of Groundwater, Vol. 33, No. 6, pp 905-908.

30 Howard, P.H., *et al.* 1991. *Handbook of Environmental Degradation Rates,* Lewis Publishers, Inc. Chelsea, Michigan.

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simulated for GRAA 2. The results of the fate and transport evaluations conducted for GRAA 3 can essentially be considered as a worst case estimate of constituent transport from GRAA 2. The output for the Series 1 through Series 3 simulations are presented as concentration versus distance and concentration versus time graphs.

The initial series of simulations (Series 1A) was performed using input parameter values favoring the worst case estimations of future constituent transport under non-pumping conditions. The input parameter values used in this evaluation are highlighted on Table 8. As discussed in the following section, this evaluation was also used as a screening process to eliminate any constituents from subsequent evaluations on the basis that sufficient attenuation can be demonstrated with the use of input parameter values favoring the worst case estimation of constituent transport.

In conjunction with the evaluations described above and at the specific request of EPA, Beazer conducted additional simulations to estimate dissolved constituent transport in groundwater under hypothetical future pumping conditions (Series 1B). As indicated previously, this scenario represents a highly improbable and extreme overestimate of constituent transport in consideration of the low probability that hydraulic gradients of the magnitude assumed for this evaluation could be produced and would be maintained over time.

Series 2 simulations involved a sensitivity analysis to evaluate the sensitivity of the modeling results to variations in estimated input parameter values. Naphthalene was utilized as a surrogate for the sensitivity analysis because it is one of more soluble and mobile of the COIs. Therefore, it is anticipated that naphthalene is best suited for determining the influence of variations of input values on the model output. The following parameters were evaluated as part of the sensitivity analysis:

- hydraulic conductivity;
- hydraulic gradient;
- effective porosity;
- fraction of organic carbon in soil; and,
- longitudinal dispersivity.

The sensitivity analysis was conducted by varying the value for a single input parameter while other input values remained constant. Estimations of constituent transport were then made using values

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of the input parameter of interest at the high and low end of the range of possible values as indicated on Table 8 and an intermediate value.

A series of simulations (Series 3) was performed using the input parameter values favoring the best case estimations of future constituent transport under non-pumping conditions. The objective of these simulations was to determine if the processes simulated by the Ogata-Banks equation (i.e., adsorption and dispersion) could be used to account for the observed constituent concentration reductions (in comparison to the effective solubility concentrations) measured in samples collected from monitoring wells located downgradient of areas where DNAPLs have been noted in the shallow aquifer.

The BIOSCREEN simulations (Series 4) were completed to incorporate the effects of biodegradation into the assessment of potential future constituent transport. As a protective measure, these evaluations were performed using the values for the necessary transport and degradation input parameters favoring a worst case estimate of constituent fate and transport due to the variability of some of these parameters within the model domain, as well as the inherent uncertainty associated with the parameter values. Use of these input parameter values ensures that the model output will not underestimate potential constituent transport in groundwater.

It is expected that migration of the creosote compounds in groundwater at the South Cavalcade Site will be limited by biodegradation. Most of these compounds are known to be biodegradable to some degree. In general, the biodegradation rates for the PAH compounds are inversely proportional to the compound molecular weight (or number of rings in the compound structure). Thus, the higher molecular weight PAHs (i.e., those with four or more rings) would be expected to degrade at a much slower rate than the lower molecular weight PAH compounds. However, it should be noted that the higher molecular weight PAHs have low aqueous solubilities and a high affinity for adsorption to aquifer sediments. Thus, these constituents typically migrate at rates several orders of magnitude less than the more mobile and more degradable creosote constituents. The scientific literature contains numerous accounts of laboratory and field studies where the intrinsic biodegradation of creosote constituents has been demonstrated under various redox conditions. Mueller et al.(1989) provided a review of several laboratory studies where biodegradation of creosote compounds (PAHs, phenolics and heterocyclics) has been demonstrated under aerobic conditions and concluded that these compounds generally have good potential for bioremediation. Grbic Galic reviewed a wide

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range of laboratory studies where the biodegradability of these types of compounds was demonstrated under generally anaerobic[31] and specifically methanogenic[32] conditions.

Results from laboratory studies support the conclusions from a wide variety of field studies showing that these compounds are also biodegradable in the environment. King et al.[33] conclusively determined that natural biodegradation was limiting the migration of a plume from a source of creosote that was emplaced below the water table for research purposes. Substantial mass transformation in the dissolved phase was noted for all monitored compounds. Over the four year study period, plumes of some compounds approached steady state, others began to shrink in size and still others continued to expand, but at a decreasing rate. Barker et al.[34] injected a slug containing benzene, toluene and xylenes (BTX) into the Borden aquifer and by monitoring the resulting plume they determined that all compounds were biodegrading and shrinking in mass as they migrated. In a similar study at Columbus Air Force Base, MacIntyre et al.[35] injected a slug containing four organics: two aromatics, a PAH and a chlorinated compound. Again, monitoring indicated substantial plume biodegradation for all compounds.

The USGS has conducted two major studies that represent intensive characterizations of natural bioremediation processes in groundwater as they relate to creosote and similar hydrocarbon mixtures.

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31 Grbic-Galic, D., 1989, *Microbial Degradation of Homocyclic and Heterocyclic Aromatic Hydrocarbons Under Anaerobic Conditions,* Developments in Industrial Microbiology, 30:237-253.

32 Grbic-Galic, D., 1990, *Methanogenic Transformation of Aromatic Hydrocarbons and Phenols in Groundwater Aquifers,* Geomicrobiology, 8:167-200.

33 King, M.W.G., J.F. Baker and K.A. Hamilton, 1995. *Natural Attenuation of Coal Tar Organics In Groundwater.* Paper Presented at the Bioremediation Symposium, April, 1995, San Diego, California.

34 Barker, J.F., G.C. Patrick and D. Major, 1987. *Natural Attenuation of Aromatic Hydrocarbons In A Shallow Sand Aquifer.* Ground Water Monitoring Review, Winter.

35 MacIntyre, W.G., M. Boggs, C.P. Antworth and T.B. Stauffer, 1993. *Degradation Kinetics of Aromatic Organic Solutes Introduced into a Heterogenous Aquifer.* Water Resources Research 29:4045-4051

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The first study was conducted at a former wood preserving site in Pensacola, Florida[36] and it concluded that substantial biodegradation was occurring as dissolved creosote compounds migrated away from the source area. The second USGS study was conducted at the site of a crude oil spill in Bemidji, Minnesota, where researchers showed that natural bioremediation was limiting the migration of a groundwater plume composed of BTEX, PAHs and other hydrocarbons. Klecka et al.[37] demonstrated natural bioremediation of PAHs and phenolic compounds in groundwater at a previous charcoal manufacturing plant in Michigan. Similarly, natural bioremediation of a plume composed of PAHs was demonstrated by Madsen et al.[38] at a coal tar disposal site in a shallow aquifer in New York State.

All of the above studies indicate that the range of compounds present in creosote are biodegradable under both controlled laboratory conditions, and in the groundwater environment. Consequently, it is expected that biodegradation will tend to limit the migration of these compounds at the South Cavalcade Site. Groundwater analyses conducted during the RI indicate reduced electron acceptor (i.e., sulfate) concentrations in monitoring well MW-01 located downgradient of the DNAPL Recovery Area in the northern section of the Site in comparison to background sulfate concentrations. These reduced concentrations of electron acceptors are indicative that intrinsic biodegradation is occurring.

Comparison of COI groundwater concentrations measured during the RI in 1987 with those measured during 1993 indicate a stabilized distribution of constituents in groundwater. Stable or reduced concentrations of the constituents of interest over time may also be an indicator of biodegradation. Additionally, benzene and toluene concentrations estimated by the Ogata-Banks analytical simulations using the input parameter values favoring a best case estimation of constituent transport are significantly greater than the actual concentrations determined through laboratory

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36 Mattraw H.C., Jr., B.J. Franks (eds) 1986. *Movement and Fate of Creosote Waste in Ground Water, Pensacola, Florida*: U.S. Geological Survey Toxic Waste-Ground Water Contamination Program. Water Supply Paper 2285.

37 Klecka, G.M., Davis, D.R. Gray and S.S. Madsen, 1990. *Natural Bioremediation of Organic Contaminants In Ground Water.* Cliffs-Dow Superfund Site. Ground Water, 28:534-543.

38 Madsen, E.L., J.L. Sinclair and W. C. Ghiorse, 1991. *In Situ Biodegradation: Microbiological Patterns In A Contaminated Aquifer.* Science, 252:830-833.

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analysis of groundwater samples. This comparison also indicates that biodegradation is effectively reducing the concentrations of constituents in groundwater.

Incorporation of biodegradation effects into the assessment allows for estimation of a "steady-state" plume configuration. Using the BIOSCREEN analytical solution with the input parameter values favoring a worst case prediction of constituent distribution, the "steady state" configurations represent estimated maximum constituent concentrations within the plume and the maximum distance that the constituents may migrate downgradient of the potential source area.

The output from the BIOSCREEN analytical solution includes a concentration versus distance graph along the centerline of the plume at the estimated "steady state" conditions. On the same graph, a second concentration versus distance plot depicting transport assuming that no degradation is occurring is provided for comparative purposes.

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4.0 DISCUSSION OF RESULTS

The results of the fate and transport simulations are discussed in this section. Where applicable, the model results are discussed relative to remedial goals specified in the ROD. For the COIs for which no remedial goals are specified in the ROD, the model results are discussed relative to the Texas Natural Resource Conservation Commission (TNRCC) Media Specific Concentrations (MSCs)[39] for groundwater. The calculated effective solubilities for some constituents are less than ROD goals or the TNRCC MSCs. As a protective measure and to account for potential uncertainty in the source concentration, the results of the fate and transport simulations for these constituents were compared to their calculated effective solubilities which represent concentrations less than the respective ROD goals or TNRCC MSCs.

As appropriate, constituents which do not exhibit a potential for migration to hypothetical future exposure points under the worst case scenario will be eliminated from further evaluation under the best case scenarios and the BIOSCREEN evaluations. A table indicating the constituents evaluated under each scenario is presented as Table 9 .

4.1 Scenario 1A -Worst Case Simulation for Non-Pumping Conditions

These fate and transport simulations were performed using the input parameter values favoring the "worst case" predictions for constituent transport under the current and reasonably expected future non-pumping conditions. Use of these input parameter values ensures that the model output will not underestimate potential constituent transport in groundwater. The results of these simulations were also used to eliminate COIs from further evaluation, as appropriate, if the results of the worst case simulations demonstrated limited mobility.

A summary of the evaluation of worst case constituent transport in the Northern and Southern Areas is provided below. The graphical outputs resulting from these simulations for the Northern and Southern areas are presented in Appendices B and C, respectively. In these appendices, a discussion of the results of the simulation for each constituent is presented followed by the graphical model output as concentration versus distance and concentration versus time plots.

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[39] Texas Natural Resource Conservation Commission Media Specific Concentrations for Groundwater - 31 Texas Administrative Code §335.568 Appendix II.

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4.1.1 Northern Area

A detailed analysis of the worst case fate and transport simulation results for the Northern Area for each COI is provided in Appendix B. This analysis includes a comparison of the simulated groundwater concentrations to the actual concentrations previously determined through laboratory analysis. The following is a brief summary of the results of this evaluation and the analysis provided in Appendix B.

- Two COIs (benzo(a)pyrene and chrysene) were eliminated from further evaluation under the remaining scenarios on the basis that the results of this worst case simulation indicated that these constituents in groundwater could not potentially migrate to the hypothetical groundwater exposure point at the evaluation levels specified above in more than 300 years. The results of previous groundwater analysis conducted at the Site during 1986 and 1987 as part of the RI and the supplemental groundwater analysis conducted in November 1993 corroborate this conclusion.

- The remaining COIs were retained for further evaluation under the remaining Ogata-Banks and BIOSCREEN scenarios. Comparison of the constituent concentrations predicted by these worst case simulations to actual groundwater concentrations reflect a significant overestimation of constituent migration potential under this assessment scenario. The significant differences between the actual and simulated concentrations are likely due to the cumulative effects of the use of values for the input parameters which favor an overestimate of constituent transport. The predicted concentrations were one to more than two orders of magnitude greater than the actual concentrations determined through laboratory analysis.

4.1.2 Southern Area

A detailed analysis of the worst case fate and transport simulation results for the Southern Area for each COI is provided in Appendix C. This analysis includes a comparison of the simulated concentrations to the actual concentrations determined through laboratory analysis. Available information regarding measured constituent concentrations in shallow groundwater include BTEX and PAH data for monitoring well MW-08 and BTEX data for monitoring well MW-17 located on the former Mobil Terminal property. Mobil monitoring well MW-17 is located between the western

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Site boundary and the hypothetical future groundwater pumping well at a distance of approximately 180 feet from the western limit of GRAA 3 (See Figure 14). Information obtained from the TNRCC files indicates that Mobil has collected groundwater samples for analysis from monitoring well MW-17 on several occasions. Results of these analyses indicate concentrations of BTEX constituents below detection limits in all instances. The following is a brief summary of the results of this evaluation and the analysis provided in Appendix C.

- Acenaphthene, anthracene, benzo(a)pyrene, chrysene, fluorene, phenanthrene and pyrene were eliminated from further evaluation under the remaining Ogata-Banks and BIOSCEEN scenarios on the basis that the results of this worst case simulation indicated that these constituents in groundwater could not potentially migrate to the hypothetical groundwater exposure point at the evaluation levels specified above in more than 300 years.

- The remaining COIs (benzene, toluene, ethylbenzene, xylene and naphthalene) were retained for further evaluation under the remaining Ogata-Banks and BIOSCREEN scenarios. Comparison of the constituent concentrations predicted by these worst case simulations to actual groundwater concentrations measured in monitoring well MW-08 and monitoring well MW-17 on the Former Mobil Terminal property reflect a significant overestimation of constituent migration potential under this assessment scenario. The significant differences between the actual and simulated concentrations are likely due to the cumulative effects of the use of values for the input parameters which favor an overestimate of constituent transport. The predicted concentrations were one to more than two orders of magnitude greater than the actual concentrations determined through laboratory analysis.

- Acenaphthene, anthracene, fluorene, naphthalene, phenanthrene and pyrene were measured at detectable concentrations one to two orders of magnitude less than the TNRCC MSCs in off-site monitoring well MW-08 which is located approximately 325 feet downgradient of the Potential DNAPL Recovery Area in the southwestern portion of the Site. However, it is likely that these constituents may originate from a source other than the South Cavalcade Site based on the presence of the less mobile of the COIs and absence of the more mobile COIs. Additionally, evaluation of the on-Site groundwater data from the November 1993 sampling event indicates that naphthalene comprises from 49% to 94% of the total PAH concentration in the on-Site samples. The maximum naphthalene to total PAH concentration

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ratio observed in the RI groundwater samples collected from monitoring well MW-08 is 14%. This observed difference in groundwater chemistry is indicative that the constituents measured during the RI in monitoring well MW-08 may have originated from a source other than the South Cavalcade Site.

Review of information presented in Section 2.0 of the RI Report indicates that several "regulated" sites exist within a one-half mile radius of the Site and releases of petroleum products in the vicinity of the Site were reported to the Houston Fire Department between 1980 and 1986. Information regarding chemical releases in the area prior to 1980 was not presented in the RI Report.

Information more recently obtained from the TNRCC files indicates that releases of petroleum based substances have occurred at the petroleum terminal located immediately west (i.e., downgradient) of the South Cavalcade Site. Information obtained included groundwater monitoring data (for BTEX constituents and TPH only) collected between 1991 and 1994. This information indicates elevated concentrations of BTEX constituents in shallow groundwater beneath the facility.

Although the source of the low levels of PAHs constituents detected in monitoring well MW-08 cannot positively be determined, the results of the fate and transport evaluations using the input parameter values which favor the greatest potential migration distance indicate that it is not feasible that these low mobility constituents could have migrated from the South Cavalcade Site to monitoring well MW-08. Additionally, review of information presented in the RI Report and information more recently obtained from the TNRCC files indicates other facilities exist in this area which have had documented releases which could potentially be the source of these constituents.

4.1.3 Scenario 1B - Worst Case Simulation for Pumping Conditions

At the specific request of EPA, Beazer conducted additional simulations to estimate dissolved constituent transport in groundwater under hypothetical future pumping conditions (Series 1B). These fate and transport evaluations were completed assuming that a groundwater withdrawal well is installed and operated at a location downgradient of and adjacent to the potential on-Site source

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areas. As indicated previously, this scenario represents a highly improbable and extreme overestimate of constituent transport in consideration of the low probability that hydraulic gradients of the magnitude assumed for this evaluation could be produced and would be maintained over time. The model output from this simulation in the form of concentration versus time plots is presented in Appendix D.

As indicated previously, future use of groundwater from the shallow aquifer is highly unlikely because 1) no groundwater production wells are installed in the shallow aquifer within a one-mile radius of the Site; 2) the HGCSD is not likely to grant permits for new groundwater wells in the Harris County area, and particularly not for any wells that would draw from the shallow aquifer underlying the Site and the surrounding area; 3) water from the public supply is currently available to all businesses and residences in the vicinity of the Site, and 4) the natural quality of the shallow groundwater may not be suitable for potable use.

These fate and transport simulations were performed using the same input parameter values used for Scenario 1A simulations (i.e., those which favor the greatest rate of constituent migration) with the exception of the hydraulic gradient. Therefore, these simulations represent "worst case" predictions for constituent transport under hypothetical future pumping conditions. The consideration of the hypothetical future groundwater withdrawal results in a four-fold increase in the magnitude of the hydraulic gradient.

As expected, the results of these simulations indicate shorter travel times to the hypothetical exposure point than those predicted by the Scenario 1A simulations. However, the registration and permitting processes established by HGSCD could provide advance notification of any future plans for use of shallow groundwater in the vicinity of the Site and allow an opportunity for an assessment of the potential risk to a future groundwater user, if any, as well as, implementation of any necessary protective actions.

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4.2 Scenario 2 - Sensitivity Analysis

A sensitivity analysis was performed to provide a quantitative evaluation of the effect of individual input parameters on the fate and transport simulation results presented in Series 1A. The sensitivity of individual input parameters was evaluated by varying the value of one parameter while the value of the other parameters remained constant. This evaluation was performed for both the Northern and Southern Areas. With the exception of the variable parameter, the input parameter values favoring the greatest potential for constituent migration were used in the sensitivity analysis.

The sensitivity analysis was completed using naphthalene as an indicator constituent. Naphthalene was selected for the sensitivity analysis because its greater effective solubility with respect to the other COIs and its moderate mobility provide for more notable effects due to input parameter variations. The results of the sensitivity analyses are presented as concentration versus distance and concentration versus time plots. Plots for the Northern and Southern Areas are included in Appendices E and F, respectively. The results of the sensitivity analysis are summarized below.

- The results of the sensitivity analysis indicate that varying the effective porosity over the range of reasonably expected values for this parameter has a relatively minor effect on the fate and transport simulation results.

- Variation of the hydraulic conductivity has a significant effect on the constituent migration rate. Use of the value at the high end of the range of hydraulic conductivity values for the Southern Area results in breakthrough at a time of approximately 60 years at a distance of 400 feet. Use of the median and low end hydraulic conductivity values for the Southern Area results in a significantly reduced rate of transport with breakthrough predicted to occur at 140 and 400 years respectively.

  For the Northern Area, relatively rapid breakthrough (less than ten years) is predicted using the high end and median values for hydraulic conductivity. While the breakthrough time for naphthalene in the Northern Area using the low end hydraulic conductivity value (40 years) is significantly greater, this simulation still predicts naphthalene concentrations much greater than the actual groundwater concentrations measured at the Site.

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- Variation of the organic carbon content has a significant effect on the constituent migration rate. Representative organic carbon content values obtained from a published source and used in this evaluation vary by nearly one order of magnitude. Thus, the predicted time for the advective front of the constituent plume to reach a particular location may also vary by approximately one order of magnitude. Predicted breakthrough times for naphthalene in the Southern Area range from approximately 80 years to more than 500 years. Predicted breakthrough times for naphthalene in the Northern Area range from less than 5 years to 40 years.

- Variation of the hydraulic gradient value also has a significant effect on the constituent migration rate. Predicted breakthrough times for naphthalene in the Southern Area range from 80 years to 200 years. Predicted breakthrough times for naphthalene in the Northern Area range from 6 years to 25 years. Predicted naphthalene concentrations using the values for hydraulic gradient at the lower end of the respective ranges are several times greater than actual concentrations determined by laboratory analysis of groundwater samples in both areas.

- Dispersivity values influence the shape of the breakthrough curve. Use of lower dispersivity values will indicate more profound changes in constituent concentrations with distance and time, as represented by a greater slope in the steeper portion of the breakthrough curve. In the early part of the curve, use of lower dispersivity values will predict lower constituent concentrations at a particular point in space. However, in the later part of the curve, an opposite relationship is observed. Use of lower dispersivity values will predict higher constituent levels. For the times and distances of interest for this simulation, use of the lower dispersivity values in the Ogata-Banks equation provides for greater predictions of constituent concentrations.

4.3 Scenario 3 - Best Case Simulation

A series of simulations was performed with the input variables set at the values specified within their respective ranges which would yield a best case prediction of constituent migration. The objective of this task was to assess whether processes not considered in the previously completed fate and

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transport evaluations, such as biodegradation, may be acting to reduce constituent concentrations in the shallow aquifer.

A summary of the evaluation of the best case Ogata-Banks simulation of constituent transport in the Northern and Southern Areas is provided below. The graphical outputs resulting from these simulations for the Northern and Southern areas are presented in Appendices G and H, respectively.

- Concentrations of benzene predicted by the best case evaluation for the Northern Area are several times greater than the actual concentrations determined through laboratory analysis. Concentrations of toluene predicted by the best case simulation are similar to those measured in Site groundwater samples. These results indicate that the reduced dissolved concentrations of these COIs observed downgradient of the potential source area cannot be accounted for entirely by adsorption and dispersion and that other processes, such as biodegradation, are acting, in conjunction with adsorption and dispersion, to reduce constituent concentrations in the shallow aquifer. The volatile aromatic compounds, such as benzene and toluene, are the more highly biodegradable of the creosote constituents. The effective intrinsic biodegradation of these constituents is well documented. Considering the biodegradability of these constituents, it is to be expected that the concentrations of these constituents are greatly overestimated by a transport model which does not account for biodegradation.

- With the exception of benzene and toluene, the concentrations predicted by these simulations were less than actual concentrations determined through laboratory analysis. Thus, the use of the input values for transport parameters which favors the lowest rate of constituent migration will most likely underestimate the rate of constituent transport in shallow groundwater.

4.4 Scenario 4 - Simulation Incorporating Biodegradation

The results of the fate and transport simulations conducted considering biodegradation effects are presented in this section. As indicated in Section 3.4, intrinsic biodegradation of creosote constituents in groundwater has been demonstrated and documented at numerous similar sites. Site-

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specific information which supports a conclusion that intrinsic biodegradation is occurring at the Site includes the following:

- Groundwater analyses conducted during the RI indicate reduced electron acceptor (i.e., sulfate) concentrations in monitoring well MW-01 located downgradient of the DNAPL Recovery Area in the northern section of the Site in comparison to background sulfate concentrations;

- Comparison of COI groundwater concentrations measured during the RI in 1987 with those measured during the 1993 pilot study indicate a stabilized distribution and concentration of constituents in groundwater; and,

- Fate and transport simulations for the more mobile and biodegradable COIs (e.g., benzene and toluene) in which the effects of biodegradation were not considered and the transport parameters, which favor a prediction of the best case distribution of constituents, were used predicted concentrations greater than or similar to those measured in on-Site downgradient monitoring wells. These results indicate that the observed decrease in concentrations of these constituents in on-Site monitoring wells cannot be attributed solely to transport processes such as adsorption and dispersion.

Based on the observations at similar sites which demonstrate the intrinsic biodegradation of creosote constituents, as well as the Site-specific information presented above, completion of most protective fate and transport evaluations which consider the effects of biodegradation are appropriate.

The BIOSCREEN simulations were performed using input parameter values which favor the greatest constituent transport and the lowest literature values for degradation rates. Use of the most protective input parameter values accounts for the inherent uncertainty related to the use of models to evaluate the fate and transport of constituents in groundwater and ensures that the model output will not underestimate potential constituent transport in groundwater. The graphical outputs resulting from these simulations for the Northern and Southern areas are presented in Appendices I and J, respectively. These appendices present the results of the simulation for each constituent as concentration versus distance plots at steady state conditions. The results of the BIOSCREEN simulations are summarized in Table 10.

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These simulations were performed to predict "steady state" conditions, assuming that biodegradation is occurring for each COI retained for further evaluation based on the results of the simulations performed under Scenario 1A. The "steady state" conditions predicted from these simulations represent the greatest constituent concentrations and migration distances assuming that biodegradation is occurring at a protectively selected rate. Also, because the lowest literature values for the degradation rates are used, the predicted times needed to attain steady state conditions should also be viewed as protective. Thus, plume migration distances and constituent concentrations greater than those predicted by these worst case simulations should not be observed in the future.

Summaries of the evaluation of constituent transport in consideration of biodegradation effects for the Northern and Southern Areas are provided below. These discussions include a comparison of the simulated concentrations to the potentially applicable groundwater criteria (i.e., ROD goals or TNRCC MSCs).

4.4.1 Simulation Incorporating Biodegradation - Northern Area

Constituents evaluated under this scenario for the Northern Area include the BTEX compounds and the following PAH compounds

- acenaphthene;
- anthracene;
- fluorene;
- naphthalene;
- phenanthrene; and,
- pyrene.

The results of these simulations are discussed below.

- The BIOSCREEN simulations performed using the most protective values for all input parameters indicate that all constituents (with the exception of pyrene) have achieved a steady state distribution in shallow groundwater assuming that no constituent releases to groundwater have occurred since wood treating operation ceased in 1962. Thus, future

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increases in concentrations of these constituents are not expected. The results of the BIOSCREEN simulation for pyrene indicate that this constituent may not have yet attained a steady-state distribution in the shallow groundwater zone. However, the simulation predicts that pyrene will be attenuated upgradient of the hypothetical future exposure point and will not migrate to the location of the hypothetical future groundwater withdrawal well.

- The BIOSCREEN simulations performed using the most protective values for all input parameters indicate that concentrations of anthracene, ethylbenzene, naphthalene, pyrene, toluene, and xylene are predicted to naturally attenuate to concentrations less than their respective ROD remedial goals or TNRCC MSCs at locations upgradient of the hypothetical future groundwater withdrawal well location.

- The BIOSCREEN simulations performed for acenaphthene, fluorene and phenanthrene also indicate that constituents will be naturally attenuated to levels below their respective TNRCC MSCs at locations upgradient of the hypothetical future groundwater withdrawal well location. However, the concentrations predicted for these constituents by the BIOSCREEN model are slightly less than those measured in Site groundwater samples. Therefore, it is possible that these simulations may not represent the worst case prediction of the steady state constituent distribution. For these constituents, additional simulations were conducted assuming lower degradation rates to develop a more protective prediction of steady state constituent distribution. The BIOSCREEN output for these simulations are presented in Appendix K. The results of these simulations indicate that these constituents are naturally attenuated to concentrations several of orders of magnitude less than their respective TNRCC MSCs upgradient of the future hypothetical groundwater withdrawal well.

- The results of the BIOSCREEN model completed for benzene using the input parameter values favoring a worst case prediction of constituent distribution simulates concentrations above the ROD remedial goal at a distance equal to the distance to the hypothetical future groundwater withdrawal well location. However, on-Site benzene concentrations predicted by this worst case simulation are more than two orders of magnitude greater than the concentrations measured in groundwater samples from on-Site monitoring well MW-01 (6 ug/l to 15 ug/l). Based on this comparison to actual measured groundwater concentrations, the results of this simulation are considered to represent a significant overestimate of the

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transport potential and steady state distribution of benzene in shallow groundwater in the Northern Area. This overestimation is likely the result of the use of the input values for transport parameters and degradation rate which favor prediction of a greater steady-state distribution of benzene in shallow groundwater in terms of migration distance and concentration.

To provide a more reasonable and reliable assessment of the natural attenuation of benzene in shallow groundwater in the Northern Area, a BIOSCREEN simulation was performed using average or median values for hydraulic conductivity, hydraulic gradient and fraction of organic carbon. A degradation half-life of 0.70 years was used for this evaluation. This degradation rate is well within the range of half-life values of 0.03 to 2 years as reported in the literature. Benzene is known to be one of the more readily degradable creosote constituents, thus, the half-life value assumed for this simulation is considered to be protective.

The BIOSCREEN output from this simulation is presented in Appendix L. As indicated, this simulation predicts that benzene concentrations will be naturally attenuated to concentrations less than the ROD goal upgradient of the hypothetical future groundwater withdrawal well location. This simulation should be viewed as a protective prediction of the steady state distribution in shallow groundwater because the BIOSCREEN results predict on-Site benzene concentrations approximately one order of magnitude greater than those measured in groundwater samples collected from the on-Site monitoring well (MW-01) located downgradient of the Northern DNAPL Recovery Area. The results of this simulation indicate that no reasonable potential exists for future exposure to this constituent in shallow groundwater.

4.4.2 Simulation Incorporating Biodegradation - Southern Area

Constituents evaluated under this scenario for the Southern Area include the BTEX compounds and naphthalene. The results of these simulations are presented below.

- The BIOSCREEN simulations performed using the input values for transport parameters and degradation rate, which favor the prediction of greater migration distances and constituent concentrations, indicate that all constituents have achieved a steady state distribution in shallow groundwater assuming that no constituent releases to groundwater have occurred

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since wood treating operations ceased at the Site in 1962. Thus, future increases in constituent levels or further constituent migration are not expected.

- Concentrations of toluene, ethylbenzene, and xylene are predicted to attenuate to concentrations less than their respective ROD remedial goals within 40 feet of the downgradient limit of the DNAPL Recovery Area in the southwestern section of the South Cavalcade Site. Likewise, concentrations of naphthalene are predicted to attenuate to concentrations less than the TNRCC MSC within 40 feet of the downgradient limit of the DNAPL Recovery Area in southwestern section of the South Cavalcade Site.

- The BIOSCREEN simulations performed using the values for input parameters, which favor the prediction of greater migration distances and constituent concentrations, indicate that concentrations of toluene, ethylbenzene, xylene and naphthalene will be attenuated to non-detectable levels at distances more than 200 feet upgradient of the hypothetical future groundwater withdrawal well location.

- The results of the BIOSCREEN model completed for benzene using the input values, which favor the prediction of greater migration distances and constituent concentrations, simulates concentrations above the ROD remedial goal at a distance equal to the distance to the hypothetical future groundwater withdrawal well location. However, benzene has not been detected in monitoring well MW-08 which is located at a distance nearer to the DNAPL Recovery Area in southwestern section of the South Cavalcade Site than the hypothetical future groundwater withdrawal well. Based on this comparison of the model simulated concentrations to actual measured groundwater concentrations, the results of this simulation are considered to represent a significant overestimate of the transport potential and distribution of benzene in shallow groundwater in the Southern Area. This overestimation is likely the result of the use of the values for transport parameters and the degradation rate which favor the prediction of greater migration distances and constituent concentrations.

To provide a more reasonable and reliable assessment of the natural attenuation of benzene in shallow groundwater in the Southern Area, a BIOSCREEN simulation was performed using average or median values for hydraulic conductivity, hydraulic gradient and fraction of organic carbon. A degradation half-life of one year was assumed for this evaluation.

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The BIOSCREEN output from this simulation is presented in Appendix M. This simulation predicts that benzene concentrations will be naturally attenuated to non-detectable concentrations at a distance more than 200 feet upgradient of the hypothetical future groundwater withdrawal well location. The results of this simulation indicate that no reasonable potential exists for future exposure to this constituent in shallow groundwater in the Southern Area.

4.5 Scenario 5 - BIOSCREEN Simulations under Pumping Conditions

BIOSCREEN simulations were performed in order to evaluate the effects of a hypothetical off-site groundwater pumping well. To support this evaluation, a groundwater flow model was used to simulate pumping effects and to calculate the travel time necessary for groundwater to migrate from the on-Site constituent source areas to the hypothetical pumping well. The estimated groundwater travel time was utilized in conjunction with the most protective hydraulic conductivity values and a median porosity value of 0.375 to back calculate the hydraulic gradient value used as input to the BIOSCREEN model. For this simulation, it was assumed that groundwater is extracted continuously at a rate of 0.5 gpm. A calculation brief and the results of these simulations are presented in Appendix N.

4.5.1 BIOSCREEN Simulations under Pumping Conditions - North Area

The following constituents were modeled for the north area as part of this scenario:

- acenaphthene;
- anthracene;
- benzene;
- ethylbenzene;
- fluorene;
- naphthalene;
- phenanthrene;
- pyrene;
- toluene; and,
- xylene.

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The model results under hypothetical pumping conditions tend to yield only slight differences in concentrations of select constituents at the location of the hypothetical groundwater pumping well. For several constituents, no change in concentration was predicted under hypothetical pumping conditions at the location of the hypothetical pumping well. Changes in predicted concentrations were for the most mobile constituents: benzene, naphthalene, ethylbenzene, and xylene with respective predicted concentrations of 2894, 726, 36, and 81 ug/L under pumping conditions. This simulation yields respective concentration increases of 55, 123, 5, and 7 ug/L for these constituents with respect to non-pumping simulations for the northern area. Results of the pumping scenario for the northern area do not change the status of these constituents with respect to their groundwater remedial goals, or in the case of naphthalene, the respective Texas Risk Reduction Standard at the location of the hypothetical groundwater pumping well.

4.5.2 BIOSCREEN Simulations under Pumping Conditions - Southern Area

The following constituents were modeled for the south area as part of this scenario:

- ethylbenzene;
- benzene;
- naphthalene;
- xylenes; and,
- toluene.

Predicted constituent concentrations at the location of the southern, hypothetical, off-Site, pumping well were consistent with concentrations modeled using BIOSCREEN under non-pumping conditions at the location of the hypothetical future groundwater pumping well, with the exception of benzene. The predicted benzene concentration at the hypothetical, off-site, groundwater pumping well under pumping conditions is 194 ug/L. The modeled benzene concentration at this location under non-pumping conditions is 100 ug/L. This difference in concentration does not affect the status of benzene with respect to its groundwater remedial goal.

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4.6 Comparison of 1986-87 and 1993 Groundwater Data

This section provides a comparison of 1986-87 and 1993 groundwater analytical data, in order to provide an indication as to whether the constituent plume is expanding, stable, or shrinking. Graphs comparing the 1986-87 and 1993 constituent concentration data for monitoring wells MW-01 and MW-04, which are located downgradient of DNAPL source areas, are included as Appendix O. These wells are the only two wells sampled at both times which are suitable for this comparison. Monitoring wells located in DNAPL source areas are not appropriate for this type of comparison due to the potential for variability in the data from possible entrainment of DNAPL in the groundwater samples collected for laboratory analysis. In this comparison, the results of the two sampling rounds conducted in 1987 serve as an indication of sampling variability. Evaluation of these data indicate that constituent concentrations did not increase in downgradient monitoring wells MW-01 and MW-04 between 1986-87 and 1993. The results of this comparison corroborate the results of the BIOSCREEN simulations which indicate that constituents in the shallow groundwater have attained a steady state distribution.

4.7 Discussion of Modeling Certainty

This section addresses potential sources of uncertainty in the modeling simulations. In particular, Ogata-Banks and BIOSCREEN simulations are compared in order to demonstrate the degree to which the models provide the same output using identical initial and boundary conditions. In addition, model results are compared to actual field data as an indication of how well the models predict actual conditions. This comparison may also serve to demonstrate that the models represent worst-case scenarios and should be considered protective.

4.7.1 Comparison of Ogata-Banks and BIOSCREEN Simulations

Ogata-Banks and BIOSCREEN simulations, assuming no degradation, were performed using the same input parameter values and boundary conditions. The results of these simulations are summarized in Table 11 and Appendix P. As indicated by the results presented in Appendix P, similar results are obtained using the two models when BIOSCREEN is run assuming no degradation and the same input parameter values are used. Table 11 displays Ogata-Banks versus BIOSCREEN results for select times and distances. Inspection of this table indicates strong agreement in the

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concentrations predicted by the two models. Slight differences in concentrations may be attributed to the possible minor accumulation of rounding errors associated with the use of input parameters and intermediate calculations for each model. Comparison of these results indicates that the two models produce nearly identical results when the same boundary conditions and input parameter values are utilized. The agreement between the modeling results supports the technical approach and modeling strategy used in this evaluation.

4.7.2 Comparison of Field Data to Simulation Results

The comparison of simulation results to actual concentration data are limited somewhat by the number of monitoring wells located downgradient of the on-Site source areas, and because the most recent groundwater monitoring event included only a portion of the existing shallow monitoring wells. Appendix Q includes graphs demonstrating the differences between the results of the analytical fate and transport simulations and actual measurements of constituent concentrations in groundwater. These results are also summarized in Table 12.

These comparisons generally confirm the anticipated differences between modeled versus measured constituent concentrations. These anticipated differences are summarized as follows:

- Worst case Ogata-Banks simulations overestimate measured concentrations;
- Best case Ogata-Banks simulations typically underestimate measured concentrations;
- Worst case, non-pumping, BIOSCREEN simulations typically overestimate measured concentrations, but to a lesser degree than the worst case Ogata-Banks simulations due to the incorporation of biodegradation effects; and,
- Worst case, pumping, BIOSCREEN simulations overestimate measured concentrations.

The factors which contribute to the discrepancies between the actual and simulated concentrations are presented in the discussions of the results for the individual modeling scenarios and sensitivity analyses (Sections 4.1 through 4.5).

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5.0 CONCLUSIONS

The fate and transport evaluations were conducted using protective assumptions regarding constituent fate and transport and potential future use of shallow groundwater to ensure that the potential for future exposure to groundwater constituents is not underestimated. The significant conclusions of the fate and transport evaluation are summarized below followed by a recommendation for future activities.

- Incorporation of biodegradation effects into the analytical model simulations is justified by the demonstration and documentation of intrinsic biodegradation of dissolved creosote constituents in groundwater at several similar Sites. Additionally, the reduced concentrations of an electron acceptor (sulfate) and the relatively stable observed constituent concentrations over time also support incorporation of biodegradation effects into the fate and transport evaluation. Also, the benzene concentrations predicted by the Ogata-Banks analytical simulations using the best case input transport parameter values are significantly greater than the actual benzene concentrations determined through laboratory analysis of groundwater samples. Thus, the reduced concentrations of benzene observed at the Site downgradient of the constituent source areas, as demonstrated by previous laboratory analyses of groundwater samples, cannot be solely attributable to adsorption and dispersion processes alone. These findings indicate that other processes, such as biodegradation, are in-fact acting to retard the migration or naturally attenuate COIs in the shallow aquifer.

- The results of the worst case BIOSCREEN simulations demonstrate effective natural attenuation of COIs within a short distance of potential constituent source areas and well before groundwater concentrations greater than the ROD remedial goals or TNRCC MSCs are realized at the nearest hypothetical future groundwater withdrawal well.

- The results of the BIOSCREEN simulations using protectively assumed constituent half-life values indicate that the COIs in the shallow groundwater have already achieved a steady state or equilibrium distribution. These simulations indicate that future migration or increasing concentrations of COI will not occur. The simulations were completed using the transport input parameter values and degradation rates which favor the prediction of greater migration distances and constituent concentrations. Thus, these simulations are considered to represent

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a protective prediction of the steady state distribution of dissolved COIs in groundwater. This conclusion is supported by a comparison of the 1986-87 groundwater concentration data with data obtained from the supplemental groundwater sampling completed in November 1993. Comparison of these data indicates stable or decreasing constituent concentrations between 1986-87 and 1993.

- The results of the worst case fate and transport simulations under non-pumping conditions predicted concentrations of the more mobile and biodegradable COIs several orders of magnitude greater than the actual concentrations determined through previous groundwater analysis. Despite the use of transport parameter values in this simulation which favor the prediction of greater migration distances and constituent concentrations, several of the higher molecular weight PAH compounds were demonstrated to be immobile and sufficiently attenuated by this overly protective evaluation.

The results of the fate and transport evaluations indicate that implementation of a natural attenuation remedy at the South Cavalcade Site is feasible. The following data collection and information gathering activities are proposed for the Northern and Southern Areas to verify the findings of the fate and transport evaluation:

Northern Area

- Install and Sample an Additional Off-Site Monitoring Well - Beazer will install an additional off-site shallow zone monitoring well located downgradient of the DNAPL source area. This well is to be located in the vicinity of the hypothetical groundwater withdrawal well considered in this fate and transport evaluation, assuming permission to install this well is granted by the City of Houston and this location is accessible to drilling equipment. A groundwater sample from this well will be analyzed for BTEX and PAHs. The groundwater analytical data obtained from sampling this additional well will be used to verify the natural attenuation of dissolved constituents in shallow groundwater.

- Install Temporary Well Screens and Conduct Groundwater Sampling - To assess the possible effects of aquifer heterogeneity in the Northern Area, groundwater samples will be collected from locations along a north-south trending line in the vicinity of the western property

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boundary (i.e., near existing monitoring well MW-01). Temporary well screens will be advanced to the base of the shallow groundwater zone using direct push techniques to permit the collection of groundwater samples. The groundwater samples will be analyzed for BTEX and PAHs. Following sample collection, the well screen will be removed and the boreholes sealed.

Southern Area

- Sample Existing Off-Site Monitoring Well - If permission from the property owner can be obtained, Beazer will conduct sampling of monitoring well MW-17 located on the former Mobil Terminal property and downgradient of GRAA 3 will be sampled and analyzed for PAHs and BTEX. If permission to sample this well cannot be obtained, then Beazer will install a new off-site shallow zone monitoring well at a downgradient location similar to Mobil monitoring well MW-17 assuming that access can be secured from the appropriate property owner. The groundwater analytical data obtained from sampling MW-17 or this new well will be used to verify the natural attenuation of dissolved constituents in shallow groundwater.

- Install Temporary Well Screens and Conduct Groundwater Sampling - To assess the possible effects of aquifer heterogeneity in the Southern Area, groundwater samples will be collected along an approximate north-south trending line in the area downgradient of GRAA 3. Sampling in this area will be contingent upon securing access from the appropriate property owner(s). Temporary well screens will be advanced to the base of the shallow groundwater zone using direct push techniques to permit the collection of groundwater samples. The groundwater samples will be analyzed for BTEX and PAHs. Following sample collection, the well screen will be removed and the boreholes sealed.

Northern and Southern Areas

- Sample Existing Monitoring Wells - Beazer will sample existing monitoring wells MW-01 and MW-08 for BTEX and PAHs, in conjunction with the sampling of the proposed wells described previously.

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- Determine Biodegradation Indicators - Beazer will determine electron acceptor (sulfate and nitrate) and dissolved oxygen concentrations at locations upgradient and downgradient of the potential source areas and ferrous iron and methane concentrations in groundwater downgradient of the potential source areas. These data will be used to support the conclusion that biodegradation is acting to reduce constituent concentrations in the shallow aquifer downgradient of the potential source areas.

- Measure DNAPL Density and Viscosity Values - Beazer will measure Site-specific DNAPL density and viscosity values for comparison to representative ranges published in the technical literature. This information will be used to support the conclusion that the DNAPL is immobile.

- Verify Groundwater Use Information - Beazer will contact the HGCSD and the City of Houston to verify the information presented in the ROD (Page 13) regarding the source of the city water supply which serves the area. Additionally, Beazer will conduct a cost analysis to evaluate the economic impracticability of groundwater use in comparison to use of water from the public supply. This evaluation will include, but not necessarily be limited to, costs of well drilling, groundwater storage facilities, installation of conveyance lines separate from those tied into public lines, utilities, and treatment costs. This information will be used to support the conclusion that future groundwater use in the vicinity of the Site is highly unlikely.

- Determine Organic Carbon Content - As shown by the sensitivity analyses, this parameter significantly influences the rate of constituent transport in groundwater. Because it is possible that the assumed values for the organic carbon content of the aquifer materials used in the fate and transport evaluations may represent an underestimate of actual Site concentrations, Beazer will determine Site-specific values for this parameter.

The specific scope of work and methodologies for implementation of these data collection activities will be presented in a work plan to be prepared by Beazer and submitted to EPA for review and

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approval. The work plan will be prepared in accordance with the EPA Data Quality Objectives Process[40].

[40] U.S. EPA, October 6, 1993, *Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process, Interim Final*, EPA QA/G-4.

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TABLES

TABLE 1
GROUNDWATER REMEDIAL GOALS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

CONSTITUENT	REMEDIAL LEVEL
Carcinogenic PAHs	no detection
Benzene	5 ug/l
Ethylbenzene	142 ug/l
Toluene	28 ug/l
Xylene	440 ug/l
Arsenic	50 ug/l
Chromium	50 ug/l
Copper	28 ug/l
Lead	50 ug/l
Zinc	100 ug/l

TABLE 2
Summary of Monitoring Well Construction Information
South Cavalcade Superfund Site
Houston, Texas
Beazer East, Inc.

Monitoring Well Designation	Top of Casing Elevation (ft-msl)	Casing Stick-Up (ft-ags)	Ground Surface Elevation (ft-msl)	Total Depth of Well (ft-bgs)	Depth to Top of Screen (ft-bgs)	Top of Screen Elevation (ft-msl)	Bottom of Screen Elevation (ft-msl)	Zone Monitored
MW01	53.24	2.9	50.34	24.00	9.0	41.34	26.34	Shallow
MW02	52.81	3.0	49.81	24.00	9.0	40.81	25.81	Shallow
MW03	51.20	2.3	48.90	24.30	14.3	34.60	24.60	Shallow
MW04	48.55	0	48.55	26.00	11.0	37.55	22.55	Shallow
MW05	52.69	1.9	50.79	22.70	12.7	38.09	28.09	Shallow
MW06	48.04	0	48.04	26.00	11.0	37.04	22.04	Shallow
MW07	51.97	3.0	48.97	30.00	10.0	38.97	18.97	Shallow
MW08	47.94	0	47.94	21.60	11.6	36.34	26.34	Shallow
MW09	46.34	0	46.34	20.00	10.0	36.34	26.34	Shallow
MW10	52.74	3.5	49.24	56.00	36.0	13.24	-6.76	Intermediate
MW11	51.66	2.9	48.76	42.00	37.0	11.76	6.76	Intermediate
MW12	53.67	3.2	50.47	52.00	42.0	8.47	-1.53	Intermediate
MW14	48.17	0	48.17	48.00	38.0	10.17	0.17	Intermediate
MW16	46.20	0	46.20	46.00	41.0	5.20	0.20	Intermediate
MW23	49.03	0	49.03	42.40	37.4	11.63	6.63	Intermediate
P01	51.82	3.3	48.52	44.90	39.9	8.62	3.62	Intermediate
P02	50.86	2.6	48.26	45.20	40.2	8.06	3.06	Intermediate
P03	51.76	3.1	48.66	38.00	33.0	15.66	10.66	Intermediate
P04	53.00	2.6	50.40	51.00	46.0	4.40	-0.60	Intermediate
P05	53.53	2.4	51.13	56.70	51.7	-0.57	-5.57	Intermediate
P06	50.47	1.5	48.97	201.50	191.5	-142.53	-152.53	Deep
P07	50.30	0	50.30	202.00	172.0	-121.70	-151.70	Deep
DW02	50.92	3.8	47.12	210.00	180.0	-132.88	-162.88	Deep
OW-01	51.48	2.0	49.48	19.10	14.1	35.38	30.38	Shallow
OW-02	52.95	2.2	50.75	20.00	15.0	35.75	30.75	Shallow
OW-06	53.67	2.7	51.00	181.00	171.0	-120.00	-130.00	Deep
OW-07	53.61	2.0	51.61	16.10	11.1	40.51	35.51	Shallow
OW-08	51.84	2.0	49.84	19.00	14.0	35.84	30.84	Shallow
OW-09	51.70	2.0	49.70	15.00	10.0	39.70	34.70	Shallow
OW-10	49.73	2.0	47.73	23.00	18.0	29.73	24.73	Shallow
OW-11	50.91	2.0	48.91	19.00	14.0	34.91	29.91	Shallow
OW-13	51.07	2.0	49.07	18.50	13.5	35.57	30.57	Shallow
OW-14	51.47	2.0	49.47	19.00	14.0	35.47	30.47	Shallow
LCW-01	NA	NA	NA	520.00	470.0	NA	NA	Deep

ft-msl = feet above mean sea level
ft-ags = feet above ground surface
ft-bgs = feet below ground surface

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TABLE 3
SUMMARY OF DENSE NON-AQUEOUS PHASE LIQUID MEASUREMENTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

SHALLOW AQUIFER		
WELL	**DNAPL THICKNESS (ft)**	**AREA**
MW-06	3.0	Southwestern
OW-02	2.25	Northern
PO-2	1.0	Northern
OW-10	Trace	Southwestern
SUMP	Trace	Northern
OW-11	Not Measured(1)	Southeastern
INTERMEDIATE AQUIFER		
WELL	**DNAPL THICKNESS (ft)**	**AREA**
MW-12	1.5	Northern
P-02	Trace	Southwestern
P-03	Not Measured(1)	Southeastern
MW-14	Not Measured(1)	Southwestern

(1) The Remedial Investigation Report indicates that DNAPLs were observed in the monitoring well during sampling. DNAPL thicknesses were not measured during the RI. DNAPL thickness measurements conducted in August 1993 did not indicate the presence of measurable DNAPL thicknesses in these wells.

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TABLE 4
REMEDIAL INVESTIGATION SOIL BORING ANALYTICAL RESULTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

		LABORATORY RESULTS	SURROGATE RESULTS
	DEPTH	TOTAL PAH	TOTAL AROMATICS
BORING ID	(feet)	(mg/kg)	(mg/kg)
A01-SB03	46	31	104
A01-SB03	54	BDL	41
A01-SB04	47	0.38	BDL
A01-SB06	47.5	708	5010
A01-SB06	59.5	BDL	32
A01-SB07	12	BDL	BDL
A01-SB09	11.5	BDL	11
A01-SB09	24	448	35
A01-SB09	51.5	BDL	7360
A01-SB09	59.5	BDL	BDL
A01-SB10	23	BDL	BDL
A01-SB11	40.5	BDL	BDL
A01-SB12	11	BDL	BDL
A01-SB12	52	BDL	BDL
A01-SB13	27	BDL	NA
A02-SB03	23.5	301	6110
A02-SB03	52.5	33	2580
A03-SB01	27.5	20	36
A03-SB02	26	38	371
A03-SB03	41	BDL	BDL
A03-SB05	13	BDL	BDL
A03-SB05	56.5	0.55	BDL
A03-SB05	60	BDL	BDL
A03-SB07	48	BDL	BDL
A03-SB07	58	BDL	BDL
A04-SB01	10.5	2503	64600
A04-SB03	61	BDL	5
A04-SB05	54	BDL	30
A05-SB01	50.5	6	55
A06-SB01	45.5	29	45
A06-SB03	51.5	28	145
A06-SB04	25	BDL	NA
A06-SB04	51	5	NA
A06-SB04	60.5	BDL	NA
A06-SB05	53.5	BDL	NA
A06-SB05	59	BDL	NA
A06-SB06	13.5	BDL	NA
A06-SB06	67.5	BDL	NA
A07-SB01	4	1062	2150
A08-SB01	65.5	BDL	BDL
A08-SB02	13	BDL	BDL
A08-SB02	42.5	BDL	12
A08-SB02	62	7	BDL

TABLE 4
REMEDIAL INVESTIGATION SOIL BORING ANALYTICAL RESULTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

		LABORATORY RESULTS	SURROGATE RESULTS
	DEPTH	TOTAL PAH	TOTAL AROMATICS
A08-SB03	55	BDL	11
A09-SB03	13.5	93	203
A09-SB03	64	BDL	BDL
A10-SB01	3.5	BDL	14600
A10-SB01	50.5	1416	767
A10-SB03	15	BDL	BDL
A10-SB03	67.5	BDL	BDL
A10-SB04	16	BDL	BDL
A10-SB04	61.5	BDL	BDL
A11-SB01	62.5	BDL	BDL
A12-SB01	15.5	5020	26600
A12-SB02	15.5	BDL	BDL
A13-SB01	3.5	8567	1300
A13-SB01	23	259	658
A13-SB02	13.5	2269	17400
A14-SB01	64	0.57	BDL
A14-SB03	14	133	341
A14-SB05	45.5	BDL	BDL
A14-SB06	11.5	BDL	BDL
A14-SB08	11.5	BDL	BDL
A14-SB08	45.5	BDL	BDL
A16-SB02	13	BDL	BDL
A16-SB02	51.5	BDL	BDL
A17-SB01	50	BDL	BDL
A17-SB02	70	BDL	BDL
A26-SB01	17.5	BDL	BDL
A26-SB01	45.5	BDL	BDL
A26-SB04	62.5	BDL	BDL
A26-SB05	50	BDL	BDL
A26-SB06	46	BDL	BDL
A26-SB07	55.5	BDL	BDL
A26-SB08	39.5	BDL	BDL
A27-SB01	4	BDL	BDL

BDL: Below Detection Limit
NA: Not Applicable

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TABLE 5
GROUNDWATER ANALYTICAL DATA - NOVEMBER 1993
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

	SAMPLE NUMBERS									
ANALYTICAL PARAMETERS	SC-MW-01[1]	SC-MW-04	SC-MW-06	SC-OW-01	SC-OW-07	SC-OW-10	SC-OW-11	SC-OW-14	LAB BLANK[2]	TRIP BLANK 1[2]
GENERAL CHEMISTRY										
BOD (5 day) mg/L[3]	NA	NA	157	NA	NA	97.0	46.0	NA	<2.0	NA
Phenol mg/L[4]	NA	NA	3410	NA	NA	3200	867	NA	<10.0	NA
Total Organic Carbon	NA	NA	65.0	NA	NA	20.0	19.0	NA	<1.0	NA
METALS[5] (Total) ug/L										
Arsenic	29.0	24.0	95.0	3.8	<1.0	22	4.8	29.0	<1.0	NA
Chromium	19.0	<6.0	<6.0	<6.0	<6.0	13.0	<6.0	15.0	<6.0	NA
Copper	<4.0	<4.0	<4.0	<4.0	<4.0	4.9	<4.0	<4.0	<4.0	NA
Manganese	1200	2000	610	8.8	140	1000	3300	1800	<1.0	NA
Lead	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	NA
Zinc	18.0	11.0	35.0	11.0	16.0	22.0	14.0	29.0	<1.0	NA
METALS (Dissolved) ug/L										
Arsenic	25.0	21.0	97.0	1.4	<1.0	23.0	3.5	9.7	<1.0	NA
Chromium	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	NA
Copper	<4.0	<4.0	<4.0	7.7	5.6	13	<4.0	9.9	<4.0	NA
Manganese	1100	1800	650	<1.0	33.0	1100	3500	1600	<1.0	NA
Lead	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	<34.0	NA
Zinc	120	11.0	15.0	130	15.0	41.0	5.9	8.5	<1.0	NA
VOLATILE ORGANIC COMPOUNDS[6] ug/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND
BTEX COMPOUNDS[7] ug/L										
Benzene	5.7	12.0	780	<2.0	<2.0	760	65.0	<2.0	<2.0	<2.0
Ethylbenze	7.7	<3.0	800	<3.0	<3.0	940	300	3.0	<3.0	<3.0
Toluene	4.5	4.6	160	<3.0	<3.0	340	120	5.1	<3.0	<3.0
Xylenes	9.1	<3.0	660	<3.0	<3.0	1000	360	20.0	<3.0	<3.0

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TABLE 5 (Continued)
GROUNDWATER ANALYTICAL DATA - NOVEMBER 1993
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

	SAMPLE NUMBERS									
ANALYTICAL PARAMETERS	SC-MW-01[1]	SC-MW-04	SC-MW-06	SC-OW-01	SC-OW-07	SC-OW-10	SC-OW-11	SC-OW-14	LAB BLANK[2]	TRIP BLANK 1[2]
SEMI VOLATILE ORGANIC COMPOUNDS[3] ug/L										
Detection Limits (per sample)	10	10	20	10	10	100	10000	10	—	—
Naphthlalene	1600 *	460 *	16000 *	2 J	1 J	15000 *	43000	2900 *	NA *	NA
Acenaphthylene	2 J	1 J	31	10 U	10 U	23 J	10000 U	15	NA	NA
Acenaphthene	65 *	95 *	360 *	1 J	10 U	460	8900 J	320 *	NA	NA
Fluorene	43	47	170 *	1 J	10 U	250	5500 J	180 *	NA	NA
Phenanthrene	26	15	300 *	2 J	10 U	410	14000	92 *	NA	NA
Anthracene	1 J	4 J	42	10 U	10 U	57 J	1800 J	23	NA	NA
Fluoranthene	1 J	6 J	95	1 J	10 U	120	7800 J	35	NA	NA
Pyrene	1 J	3 J	56	1 J	10 U	69 J	3400 J	19	NA	NA
Benzo (A) Anthracene	10 U	10 U	19 J	1 J	10 U	15 J	1300 J	3 J	NA	NA
Chrysene	10 U	10 U	12 J	1 J	10 U	10 J	1100 J	3 J	NA	NA
Benzo (B) Fluoranthene	10 U	10 U	9 J	2 J	10 U	6 J	490 J	2 J	NA	NA
Benzo (K) Fluoranthene	10 U	10 U	20 U	10 U	10 U	3 J	10000 U	1 J	NA	NA
Benzo (A) Pyrene	10 U	10 U	3 J	1 J	10 U	2 J	10000 U	1 J	NA	NA
Indeno (1,2,3-CD) Pyrene	10 U	10 U	20 U	10 U	10 U	100 U	10000 U	10 U	NA	NA
Dibenzo (A,H) Anthracene	10 U	10 U	20 U	10 U	10 U	100 U	10000 U	10 U	NA	NA
Benzo (GHI) Perylene	10 U	10 U	20 U	10 U	10 U	100 U	10000 U	10 U	NA	NA

NOTES:
(1) Sample Identification; SC = South Cavalcade; MW = monitoring well; OW = observation well
(2) Quality control samples
(3) Units are in milligrams per liter
(4) Units are in micrograms per liter
(5) Analytical methods used are USEPA SW846 Method 6010/7000
(6) Analytical method used is USEPA SW846 Method 8240
(7) Analytical method used is USEPA SW846 Method 8020
(8) Analytical method used is USEPA SW846 Method 8270
NA - Not Analyzed
ND - Not Detected
* Compound amount determined from dilution
U - Undetected at the listed detection limit
J - Compound is present but below the listed detection limit.

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TABLE 6

SUMMARY OF GROUNDWATER ANALYTICAL DATA
MOBIL TERMINAL MONITORING WELL MW-17
HOUSTON TEXAS

Date	Benzene ug/l	Toluene ug/l	Ethyl-Benzene ug/l	Xylenes ug/l	Total BETX ug/l	Total Petroleum Hydrocarbon ug/l
5/28/92	ND	ND	ND	ND	ND	ND
9/11/92	ND	ND	ND	ND	ND	ND
11/25/92	ND	ND	ND	ND	ND	ND
11/30/93	ND	ND	ND	ND	ND	ND

TABLE 7
EFFECTIVE SOLUBILITY AND ORGANIC CARBON PARTITIONING COEFFICIENTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

Compound	Effective Solubility (ug/l)[1]	K_{oc}[2]
Acenaphthene	1.785×10^{3}	5.01×10^{3}
Anthracene	3.390×10^{2}	1.26×10^{4}
Benzene	3.799×10^{3}	6.46×10^{1}
Benzo(a)anthracene	3.000×10^{0}	1.38×10^{6}
Benzo(a)pyrene	8.000×10^{-2}	5.50×10^{6}
Benzo(g,h,i)perylene	5.000×10^{-2}	1.58×10^{6}
Chrysene	1.000×10^{0}	2.00×10^{5}
Ethylbenzene	2.920×10^{2}	6.76×10^{2}
Fluoranthene	9.300×10^{1}	3.80×10^{4}
Fluorene	8.810×10^{2}	7.94×10^{3}
Naphthalene	1.273×10^{4}	1.29×10^{3}
Phenanthrene	5.980×10^{2}	1.26×10^{4}
Pyrene	1.090×10^{2}	3.80×10^{4}
Toluene	1.041×10^{3}	2.57×10^{2}
Xylenes	3.130×10^{2}	6.92×10^{2}

1) Effective Solubility — Feenstra S. and J.A. Cherry, 1990
Groundwater Contamination by Cresote
In *Proceedings from the Eleventh Annual Meeting of the Canadian Wood Preserving Association,*
Toronto, Canada

2) Organic Carbon Partition Coefficient (K_{oc}) — U.S. EPA, 1990, *Subsurface Remediation Guidance,* EPA/540/2-90/011b.

TABLE 8
MODEL INPUT PARAMETERS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

K (ft/yr)[1]		I (ft/ft)[2]		I_p (ft/ft)[3]		n[4]		P_b (g/cm^3)[6]		f_{oc}[7]		a_x (feet)[8]	
Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
North Area													
7173.63	38149.80	0.00176	0.00588	0.01740	0.02320	0.25	0.50 0.375	1.325	1.988	8.6×10^{-4}	5.7×10^{-3}	1.6	16
South Area													
675.45	2612.28	0.00257	0.00571	0.01875	0.02500	0.25	0.50 0.375	1.325	1.988	8.6×10^{-4}	5.7×10^{-3}	1.6	16

1) Hydraulic Conductivity (K): **NORTH AREA** - McLaren/Hart Environmental Engineering Corporation October 1993, *Groundwater Collection Trench Pilot Study Report.* **SOUTH AREA** - Keystone Environmental Resources, Inc., July 1992, *Extraction Well Pilot Study Report, South Cavalcade Site, Houston, Texas*

2) Hydraulic Gradient (i): Keystone Environmental Resources,Inc., July 1988, *Final Report - Remedial Investigation, South Cavalcade Site, Houston, Texas*

3) Hydaulic Gradient (i_p): Estimated hydraulic gradient assuming a downgradient, offsite pumping well.

4) Effective Porosity (n): Freeze, R.A. and J.A. Cherry, *Groundwater,* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1979.

5) Groundwater Seepage Velocity (v_s): Calculated from 1, 2, and 3.

6) Bulk Density (P_b) Freeze, R.A. and J.A. Cherry, *Groundwater,* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1979.

7) Fraction of Organic Carbon (f_{oc}): Karickhoff, S.W., D.S. Brown, and T.A. Scott, 1979. Sorption of Hydrophobic Pollutants of Natural Sediments, *Water Research,* Vol. 13, pp 241-248.

8) Dispersivity (a_x): Gelhar, et al, 1985 *A Review of Field Scale Physical Solute Transport Process in Saturated and Unsaturated Porous Media,* Electric Power Research Institute, Palo Alto, California.

Represents input paramater that will yield conservative output.

Median value used.

Note: Extra digits maintained for calculated values in order to reduce rounding errors during subsequent modeling.

TABLE 9

SUMMARY OF MODEL SIMULATION CONSTITUENTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS

Compound	Scenario 1A	Scenario 1B	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Acenaphthene	N,S	N,S	—	N	N	N
Anthracene	N,S	N,S	—	N	N	N
Benzene	N,S	N,S	—	N,S	N,S	N,S
Benzo(a)pyrene	N,S	N,S	—	—	—	—
Chrysene	N,S	N,S	—	—	—	—
Ethylbenzene	N,S	N,S	—	N,S	N,S	N,S
Fluorene	N,S	N,S	—	N	N	N
Naphthalene	N,S	N,S	N,S	N,S	N,S	N,S
Phenanthrene	N,S	N,S	—	N	N	N
Pyrene	N,S	N,S	—	—	N	N
Toluene	N,S	N,S	—	N,S	N,S	N,S
Xylenes	N,S	N,S	—	N,S	N,S	N,S

'N' represents modeling scenarios performed for a constituent in the North Area.
'S' represents modeling scenarios performed for a constituent in the South Area.
'—' indicates not evaluated.

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TABLE 10
SUMMARY OF BIOSCREEN MODEL RESULTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.

NORTHERN AREA					
Constituent	Time to Attain Steady State Condition (years)	Biodegradation Half-Life Used in Simulation	Literature Values for Biodegradation Half-Life	Potentially Applicable Groundwater Criteria (ug/l)	Predicted Steady-State Groundwater Concentration at Hypothetical Future Exposure Point (ug/l)
Acenaphthene	6	204 days	25 - 204 days	2,190 (1)	0.0
Acenaphthene	12	1.19 years	25 - 204 days	2,190 (1)	7
Anthracene	22	2.5 years	100 days - 2.5 years	11,000 (1)	1
Benzene	3	2 years	10 days - 2 years	5 (2)	3,190
Benzene	8	0.7 years	10 days - 2 years	5 (2)	3
Ethylbenzene	5	228 days	6 - 228 days	142 (2)	31
Fluorene	3	120 days	64 - 120 days	1,460 (1)	0.0
Fluorene	21	2.05 years	64 - 120 days	1,460 (1)	6
Naphthalene	8	258 days	1- 258 days	1,460 (1)	603
Phenanthrene	9	1.1 years	32 days - 1.1 years	11,000 (1)	0.0
Phenanthrene	24	3.07 years	32 days - 1.1 years	11,000 (1)	3

TABLE 10
SUMMARY OF BIOSCREEN MODEL RESULTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.
(Page 2)

NORTHERN AREA					
Constituent	Time to Attain Steady State Condition (years)	Biodegradation Half-Life Used in Simulation	Literature Values for Biodegradation Half-Life	Potentially Applicable Groundwater Criteria (ug/l)	Predicted Steady-State Groundwater Concentration at Hypothetical Future Exposure Point (ug/l)
Pyrene	74	10.4 years	1.15 - 10.4 years	1,100 (1)	1.0
Toluene	0.7	28 days	7-28 days	28 (2)	0.0
Xylene	6	365 days	14 days - 365 days	440 (2)	74
SOUTHERN AREA					
Benzene	18	2 years	10 days - 2 years	5 (2)	100
Benzene	13	1 year	10 days - 2 years	5 (2)	0.0
Ethylbenzene	4	228 days	6 - 228 days	142 (2)	0.0
Naphthalene	10	258 days	1- 258 days	1,460 (1)	0.0
Toluene	0.8	28 days	7-28 days	28 (2)	0.0
Xylene	8	365 days	14 days - 365 days	440 (2)	0.0

TABLE 10
SUMMARY OF BIOSCREEN MODEL RESULTS
SOUTH CAVALCADE SUPERFUND SITE
HOUSTON, TEXAS
BEAZER EAST, INC.
(Page 3)

(1) Texas Natural Resource Conservation Commission Media Specific Concentrations for Groundwater - 31 Texas Administrative Code §335.568 Appendix II.

(2) Groundwater Remedial Goal Specified in the Record of Decision for the South Cavalcade Superfund Site.

Table 11

Comparison of Ogata-Banks and BIOSCREEN Simulation Results

Naphthalene - North Area

	Concentration (*u*g/L)	Distance (feet)	Time (years)
Ogata-Banks	5977	125	1
BIOSCREEN	5976	125	1
Ogata-Banks	8725	425	4
BIOSCREEN	8724	425	4
Ogata-Banks	8631	650	6
BIOSCREEN	8629	650	6

Naphthalene - South Area

	Concentration (*u*g/L)	Distance (feet)	Time (years)
Ogata-Banks	5941	125	15
BIOSCREEN	5942	125	15
Ogata-Banks	6554	400	50
BIOSCREEN	6555	400	50
Ogata-Banks	6592	800	100
BIOSCREEN	6594	800	100

TABLE 12

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Data Summary

	Field Data	Scenario 1A	Scenario 3	Scenario 4	Scenario 5
Benzene (ug/L)					
North Area	5.7	3799	3799	3190	3227
South Area	5 U	3799	0	207	352
Ethylbenzene (ug/L)					
North Area	7.7	292	0	77	83
South Area	5 U	210	0	0	0
Toluene (ug/L)					
North Area	4.5	1040	1040	6	9
South Area	5 U	1040	0	0	0
Xylene (ug/L)					
North Area	9.1	313	0	131	139
South Area	5 U	313	0	0	0
Naphthalene (ug/L)					
North Area	1600	12700	0	2043	2283
South Area	24	6000	0	0	0
Fluorene (ug/L)					
North Area	43	881	0	0	0
South Area	20	0	0	NA	NA
Acenaphthene (ug/L)					
North Area	65	1790	0	4	5
South Area	22	0	0	NA	NA
Phenanthrene (ug/L)					
North Area	26	598	0	0	0
South Area	57	0	0	NA	NA

Scenario 1A - Ogata-Banks ("Worst Case")
Scenario 3 - Ogata-Banks ("Best Case")
Scenario 4 - BIOSCREEN - Non-Pumping ("Worst Case")
Scenario 5 - BIOSCREEN - Pumping ("Worst Case")

NA = not analyzed
U = constituent was not detected at the listed detection level
ug/L = micrograms per liter

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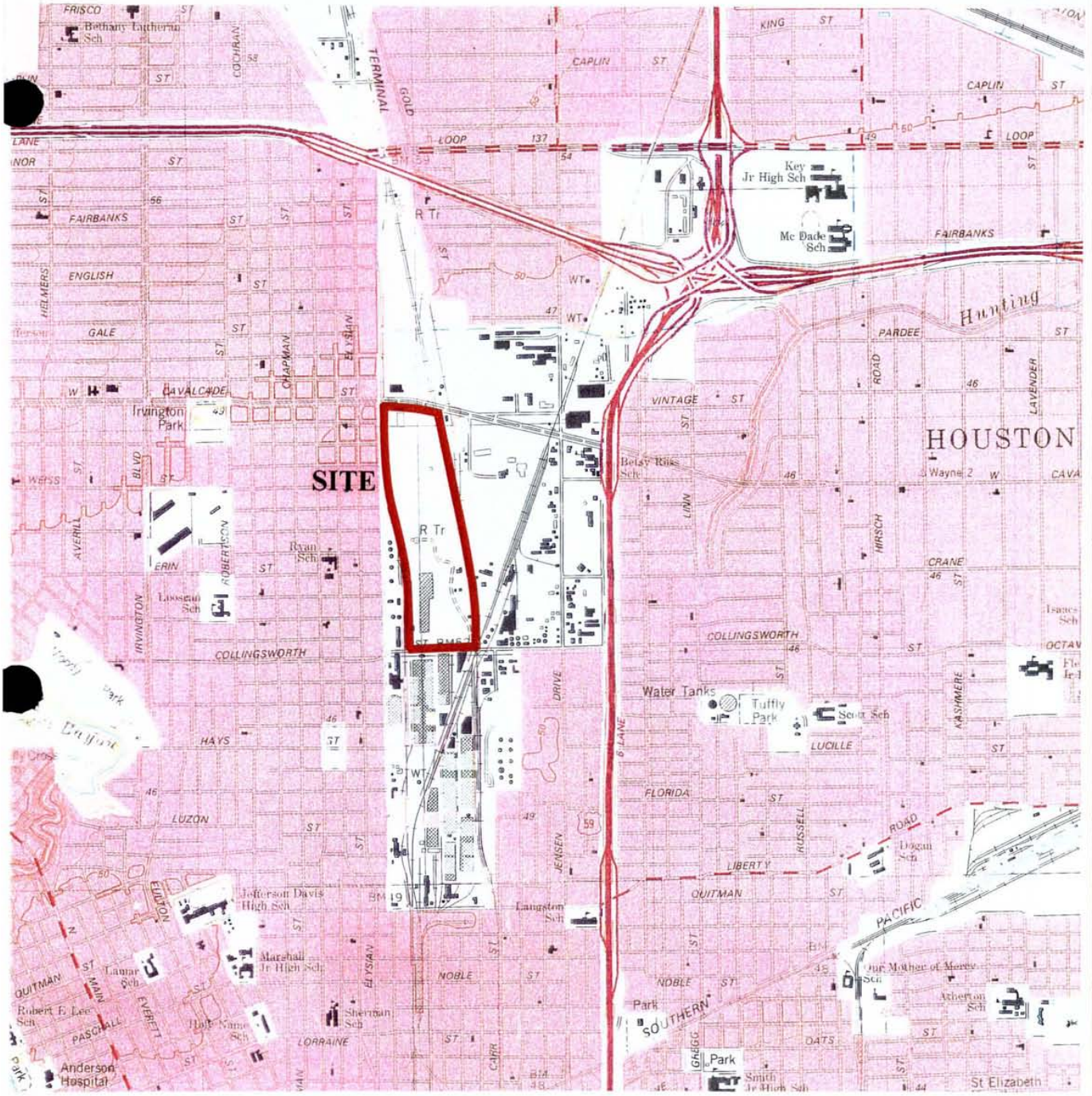
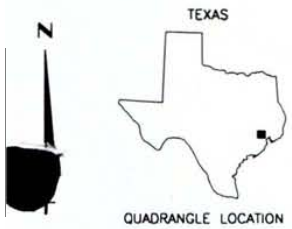
FIGURES





QUADRANGLE LOCATION

REFERENCE: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE OF SETTEGAST, TEXAS

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN:	MEL	DATE:	09/04/96
CHKD:	JRH	DATE:	09/04/96
APPD:	JSZ	DATE:	09/04/96
SCALE:	1" = 2000'		

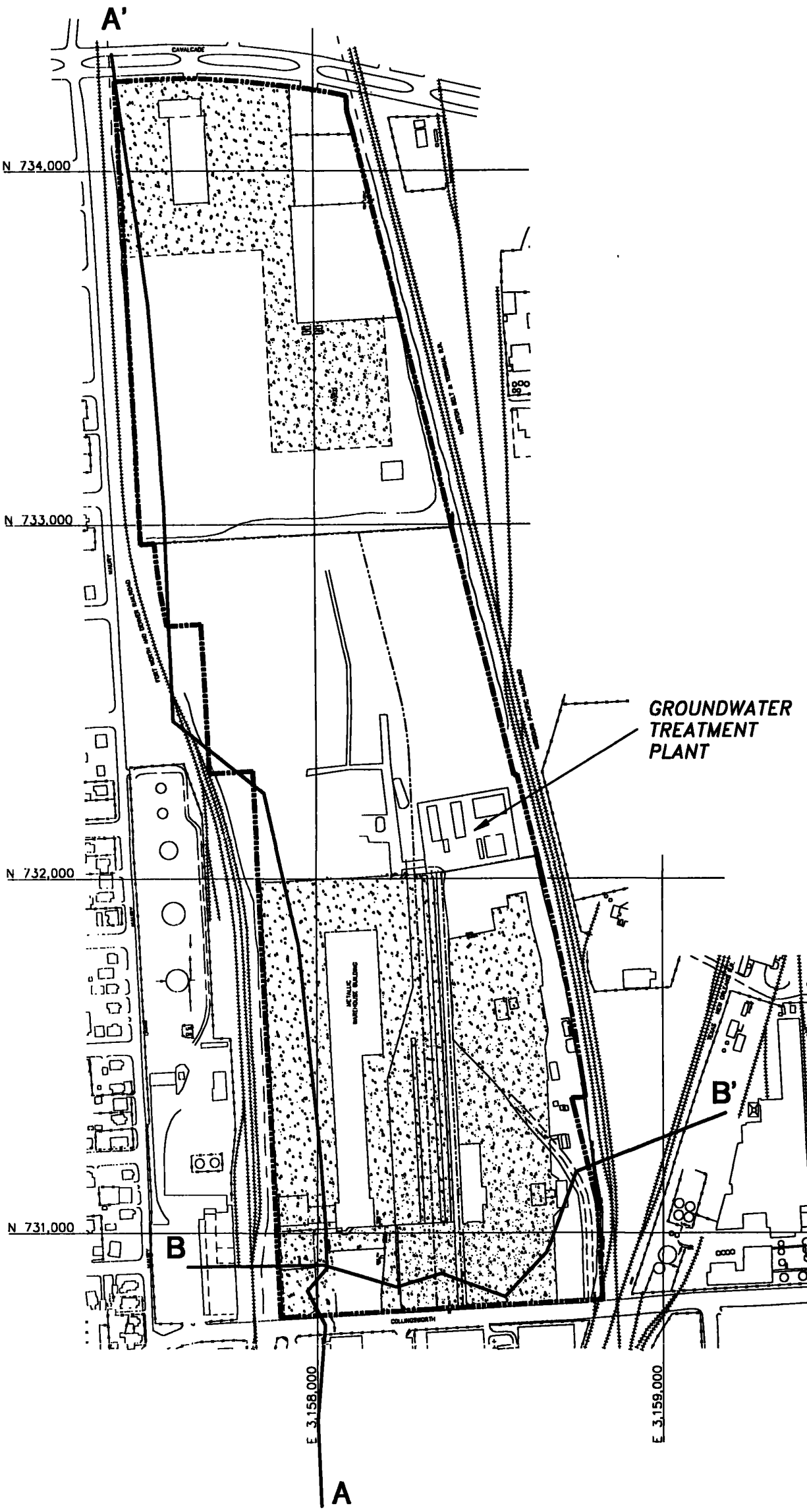
KEY ENVIRONMENTAL INCORPORATED

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

SITE LOCATION MAP

DRAWING NUMBER
96118
FIGURE 1

EDITED BY:	DATE:	TIME:	EDITING TIME:	DRAWING NAME: G:\CAD\CAD\98118\FIG-002.DWG



N

LEGEND:

- SOUTH CAVALCADE SITE BOUNDARY
- PROPERTY BOUNDARIES
- B — B' CROSS SECTION LOCATION
- AREAS COVERED WITH ASPHALT OR CONCRETE

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/22/97	KEY ENVIRONMENTAL INCORPORATED
CHKD: JSZ	DATE: 01/22/97	
APPD: JSZ	DATE: 01/22/97	
SCALE: AS SHOWN		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

SITE PLAN

DRAWING NUMBER 98118
FIGURE 2

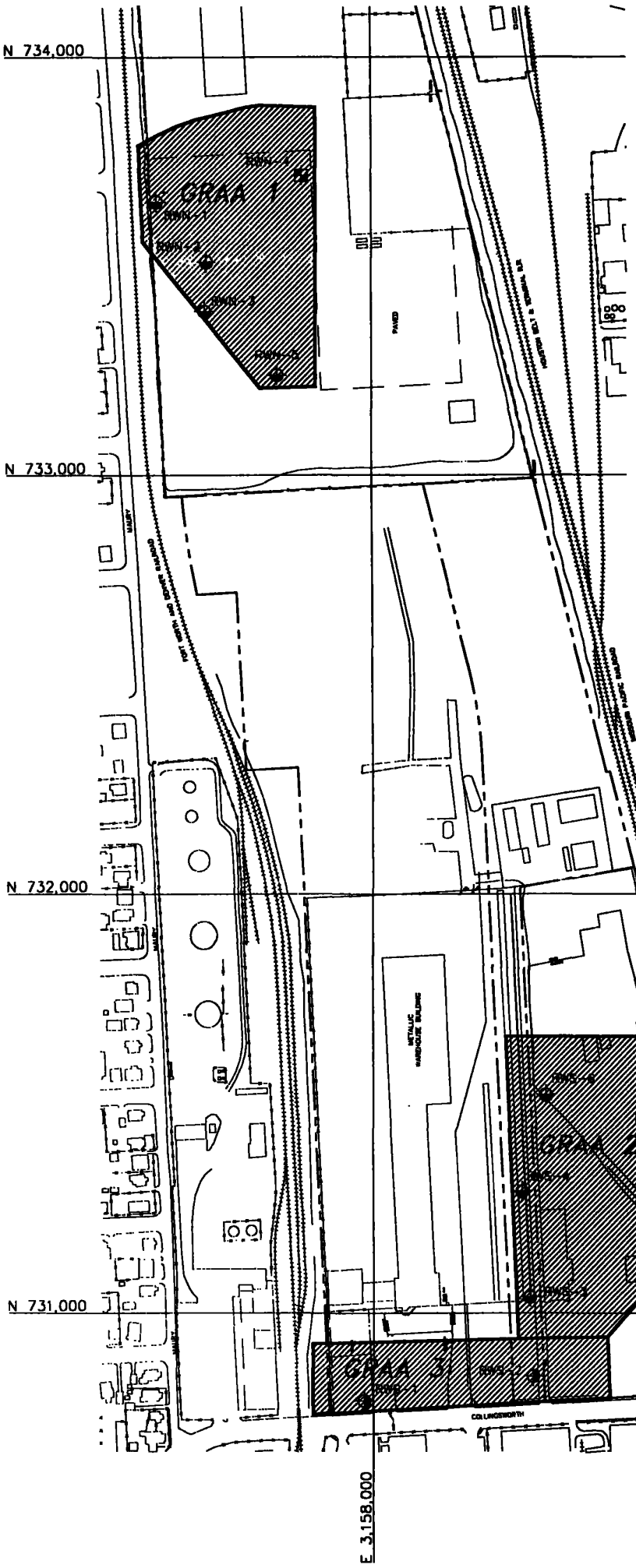
REV #	DATE	DESCRIPTION	APPD

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

EDITED BY:	DATE:	TIME:	EDITING TIME:	DRAWING NAME: C:\CAVALCADE\96118\FIG-03D.DWG



LEGEND:

- GROUNDWATER EXTRACTION WELL (FOR HYDRAULIC CONTAINMENT)
- DNAPL AND GROUNDWATER EXTRACTION WELL (FOR HYDRAULIC CONTAINMENT AND SOURCE CONTROL)
- DNAPL RECOVERY WELL LOCATION (FOR SOURCE CONTROL)
- GROUNDWATER REMEDIAL ACTION AREA (GRAA)

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRWN:	MEL	DATE: 01/23/97	KEY ENVIRONMENTAL INCORPORATED
CHKD:	JSZ	DATE: 01/23/97	
APPD:	JSZ	DATE: 01/23/97	
SCALE:	AS SHOWN		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

REV #	DATE	DESCRIPTION	APPD
1			
2			
3			

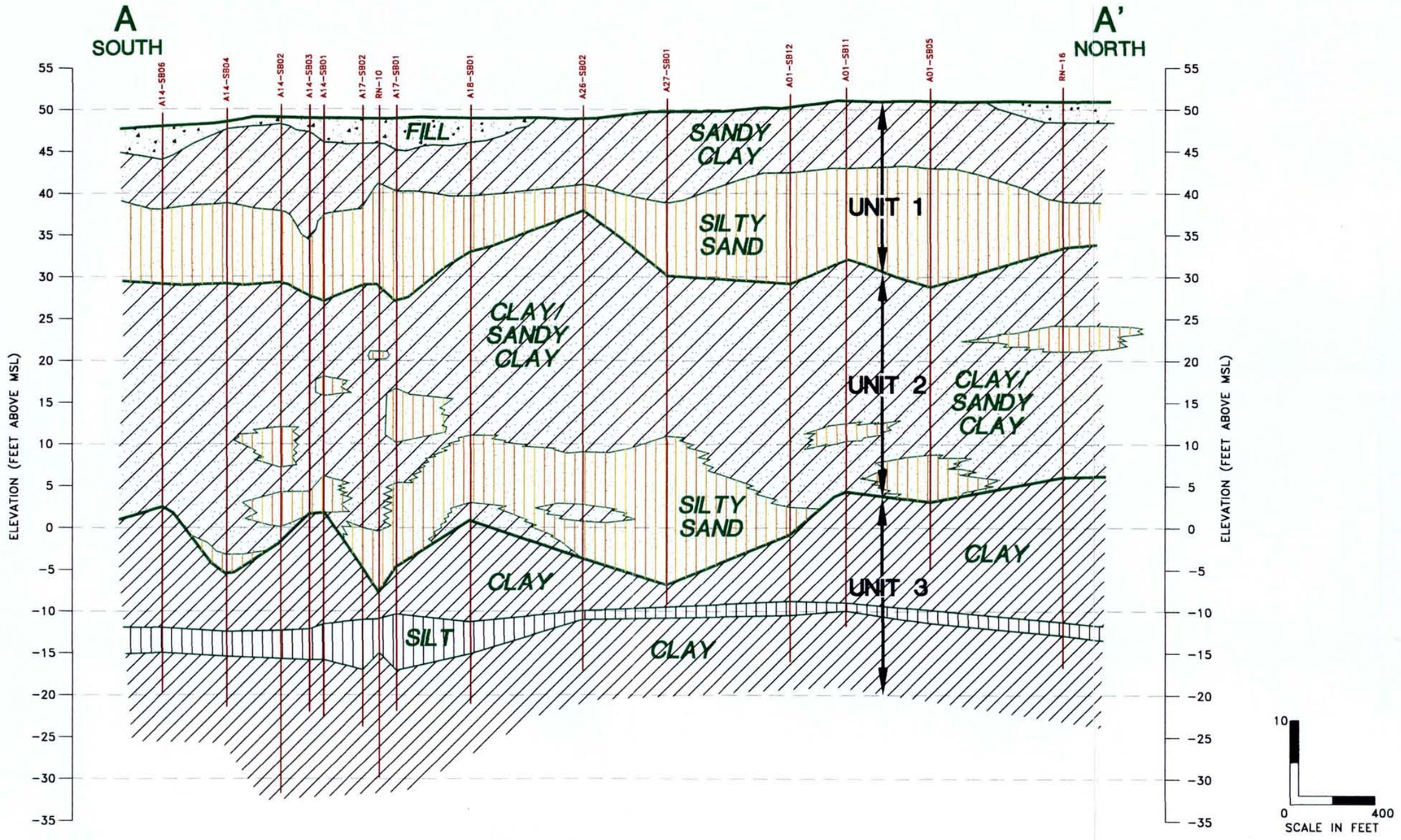
KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

GROUNDWATER REMEDIAL ACTION AREAS AND GROUNDWATER COLLECTION AND DNAPL RECOVERY WELL LOCATIONS

DRAWING NUMBER 96118
FIGURE 3



LEGEND:

- FILL
- CLAY
- SANDY CLAY
- SILT
- SILTY SAND

REV #	DATE	DESCRIPTION	APPD
1			
2			
3			

REFERENCE: FIGURE 4-4C, GENERALIZED GEOLOGIC PROFILE,REMEDIAL INVESTIGATION REPORT, SOUTH CAVALCADE SITE, KEYSTONE ENVIRONMENTAL RESOUCES, INC., JULY 1988.

LOCATION OF CROSS-SECTION SHOWN ON FIGURE 3.

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

BEAZER EAST, INC
PITTSBURGH, PENNSYLVANIA

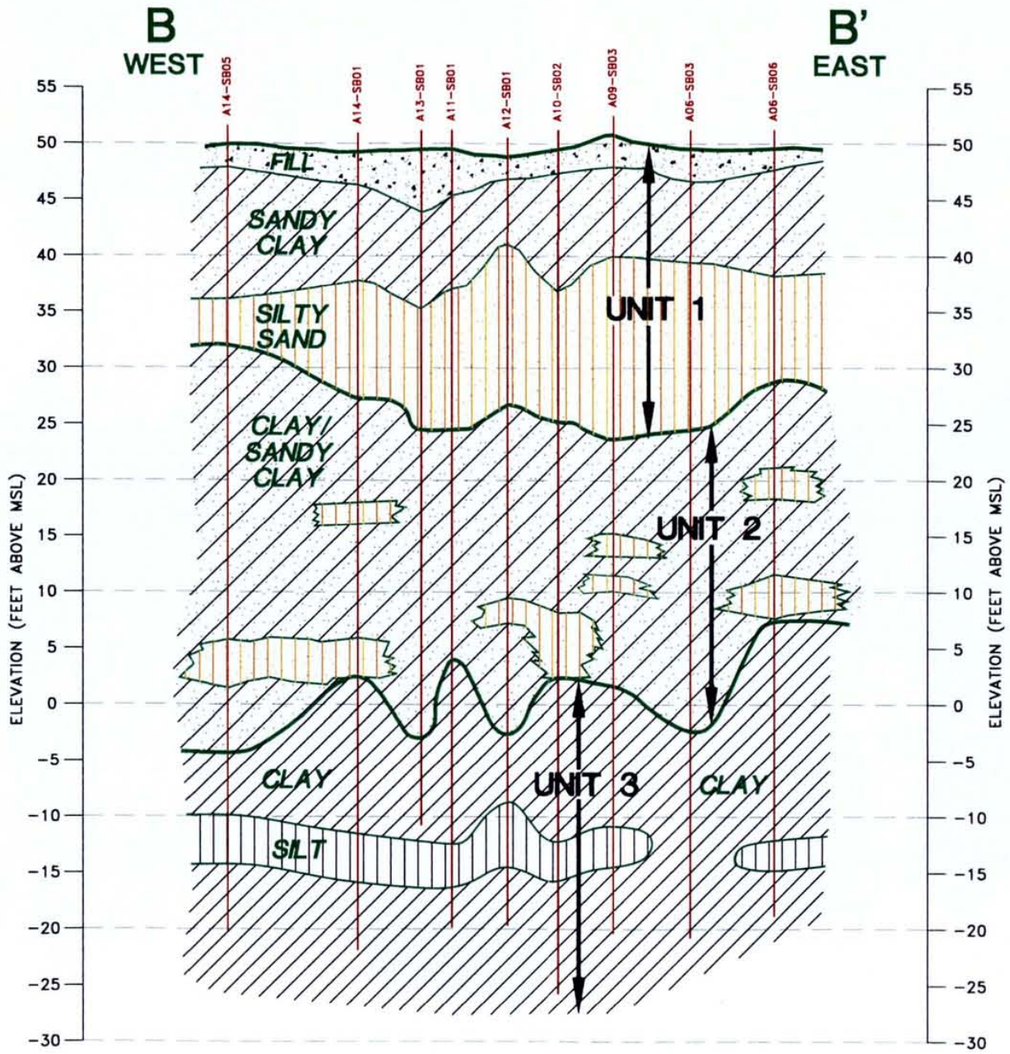
DRAWN: MEL	DATE: 01/24/97	KEY ENVIRONMENTAL INCORPORATED
CHKD: JSZ	DATE: 01/24/97	
APPD: JSZ	DATE: 01/24/97	
SCALE: AS SHOWN		

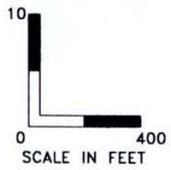
SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

GEOLOGIC
CROSS-SECTION A-A'

DRAWING NUMBER
96118
FIGURE 4

EDITED BY: | DATE: | TIME: | EDITING TIME: | DRAWING NAME: C:\CAVALCAD\96118\FIG-04.DWG





LEGEND:

- FILL
- SANDY CLAY
- SILTY SAND
- CLAY
- SILT

REV #	DATE	DESCRIPTION	APPD
1			
2			
3			

REFERENCE: FIGURE 4-4D, GENERALIZED GEOLOGIC PROFILE,REMEDIAL INVESTIGATION REPORT, SOUTH CAVALCADE SITE, KEYSTONE ENVIRONMENTAL RESOUCES, INC., JULY 1988.

LOCATION OF CROSS-SECTION SHOWN ON FIGURE 3.

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

BEAZER EAST, INC
PITTSBURGH, PENNSYLVANIA

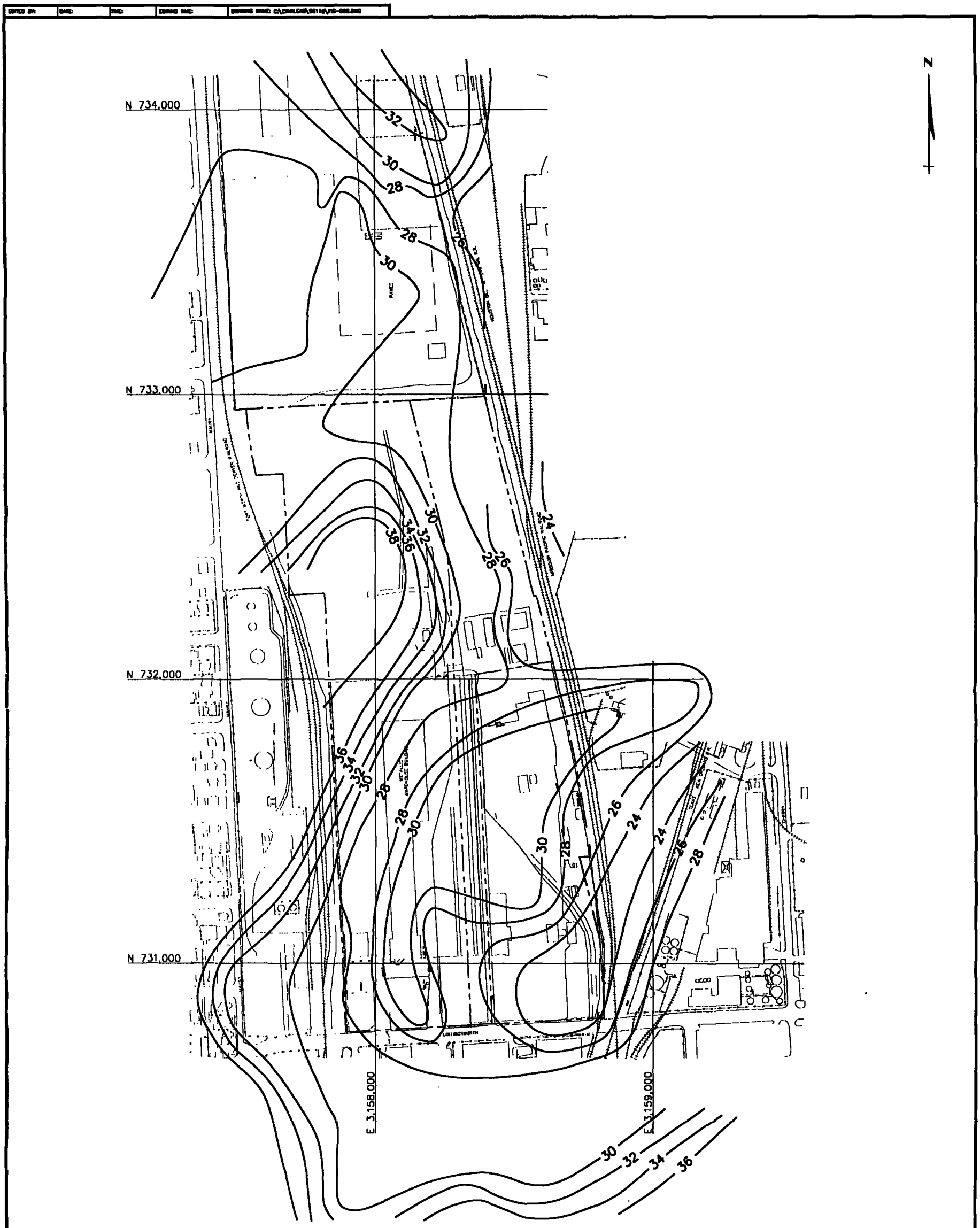
DRAWN: MEL	DATE: 01/24/97	KEY ENVIRONMENTAL INCORPORATED
CHKD: JSZ	DATE: 01/24/97	
APPD: JSZ	DATE: 01/24/97	
SCALE: AS SHOWN		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

GEOLOGIC
CROSS-SECTION B-B'

DRAWING NUMBER
98118
FIGURE 5

EDITED BY: | DATE: | TIME: | EDITING TIME: | DRAWING NAME: C:\CAVALCADE\98118\FIG-05B.DWG



BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/22/97	KEY ENVIRONMENTAL INCORPORATED	
CHKD: JSZ	DATE: 01/22/97		
APPD: JSZ	DATE: 01/22/97		
SCALE:	AS SHOWN		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

TOP OF CONFINING UNIT
CONTOUR MAP

DRAWING NUMBER 96118
FIGURE 6

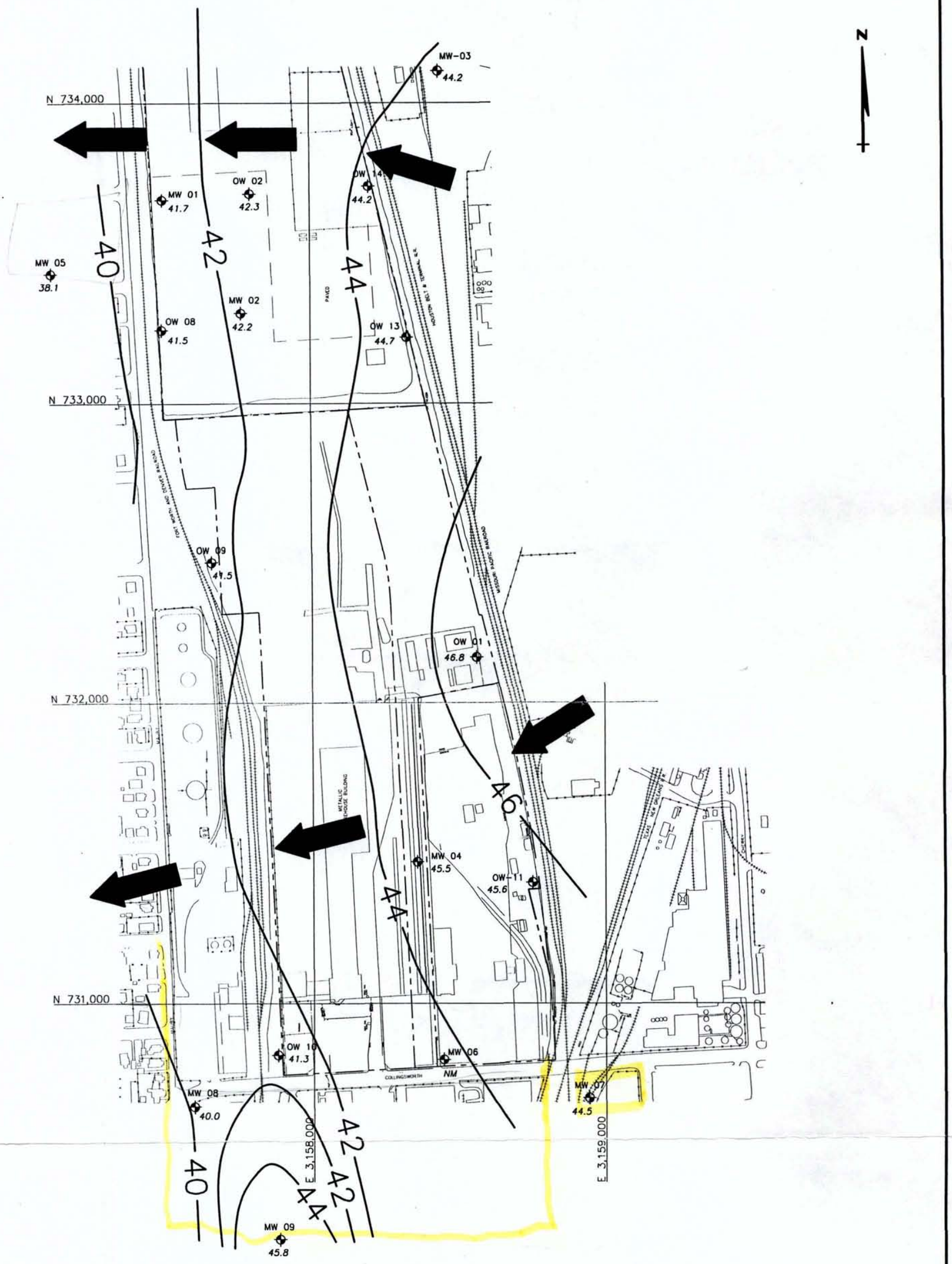
REV #	DATE	DESCRIPTION	APPD
△			
△			
△			

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

EDITED BY:	DATE:	TIME:	EDITING TIME:	DRAWING NAME: C:\CAVALCAD\96118\FIG-07B.DWG



LEGEND:

—42—	SHALLOW AQUIFER POTENTIOMETRIC SURFACE CONTOURS C.I.=2'
	INTERPRETED GROUNDWATER FLOW DIRECTION
45.8	SHALLOW AQUIFER MONITORING WELL POTENTIOMETRIC ELEVATION
NM	NOT MEASURED

REV #	DATE	DESCRIPTION	APPD
△			
△			
⚠			

REFERENCE: KEYSTONE ENVIRONMENTAL RESOURCES, INC., FINAL REPORT REMEDIAL INVESTIGATION KOPPERS COMPANY, INC. SOUTH CAVALCADE SITE, HOUSTON, TEXAS, JULY 1988, FIGURE 4-14.

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/22/97	KEY ENVIRONMENTAL INCORPORATED	
CHKD: JSZ	DATE: 01/22/97		
APPD: JSZ	DATE: 01/22/97		
SCALE: AS SHOWN			

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

SHALLOW AQUIFER POTENTIOMETRIC SURFACE MAP

DRAWING NUMBER 96118
FIGURE 7

NOTES :

1. SOIL BORINGS DENOTED WITH RM PREFIX FROM McCLELLAND ENGINEERS REPORT GEOTECHNICAL INVESTIGATION RECONNAISSANCE STUDY CAVALCADE YARD AND SHOP, METRO-STAGE ONE, RRS (VOL. VII) DATED MAY 20, 1983.
2. SOIL BORINGS DENOTED WITH RN PREFIX FROM McCLELLAND ENGINEERS REPORT GEOTECHNICAL DATA REPORT RECONNAISSANCE STUDY, NORTH CORRIDOR METRO-STAGE ONE, RRS (VOL. V) DATED MAY 6, 1983.
3. ALL BORING AND MONITORING WELL LOCATIONS ARE APPROXIMATE.
4. MONITORING WELLS DENOTED WITH OW PREFIX FROM CAMP DRESSER & McKEE REPORT TO HOUSTON TRANSIT CONSULTANTS – CAVALCADE CONTAMINANT SURVEY VOLUME 1 – ENGINEERING REPORT DATED JULY 11, 1983.
5. MONITORING WELLS DENOTED WITH MW, P, AND DW ARE PART OF THIS REMEDIAL INVESTIGATION STUDY.

LEGEND

- ● SOIL BORING
- ▲ CONE PENETROMETER SOUNDING
- ■ SOIL BORING BY OTHERS
- □ SHALLOW ZONE MONITORING WELL
- ○ SHALLOW ZONE MONITORING WELL (BY OTHERS)

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN:	MEL	DATE: 01/21/97
CHKD:	JEE	DATE: 01/21/97
APPD:	JEE	DATE: 01/21/97
SCALE:	1" = 300'	

KEY ENVIRONMENTAL INCORPORATED

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

DRAWING NUMBER 96116

REMEDIAL INVESTIGATION
SOIL BORING LOCATIONS

FIGURE 8

KEY ENVIRONMENTAL INC. ISSUE DATE:

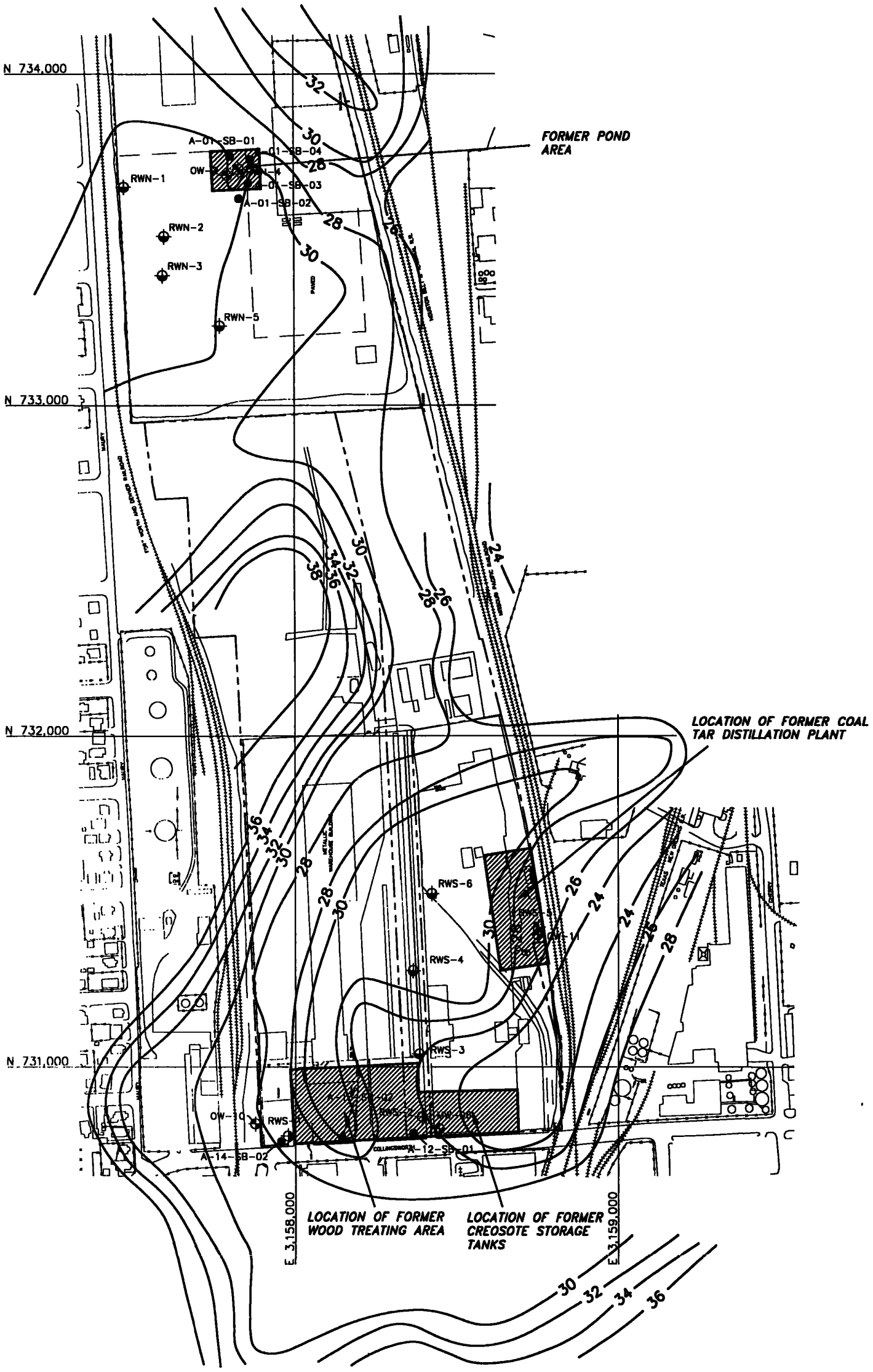
ROSLYN FARMS INDUSTRIAL PARK 1300 ARCH ST., SUITE 300 CHESTER, PA. 19096

REFERENCE: FIGURE 3-4, SOIL BORING AND GROUNDWATER MONITORING WELL LOCATION MAP, REMEDIAL INVESTIGATION REPORT, SOUTH CAVALCADE SITE, KEYSTONE ENVIRONMENTAL RESOURCES, INC., JULY, 1988.

REV #	DATE	DESCRIPTION	APPD

DRAWING NAME: C:\CAVALCADE\96116\FIG-SBLOC

DRAWN: MEL | DSGN: | CHKD: JEE | APPD: JEE



LEGEND:

- GROUNDWATER EXTRACTION WELL (FOR HYDRAULIC CONTAINMENT)
- DNAPL AND GROUNDWATER EXTRACTION WELL (FOR HYDRAULIC CONTAINMENT AND SOURCE CONTROL)
- DNAPL RECOVERY WELL LOCATION (FOR SOURCE CONTROL)
- SHALLOW MONITORING WELLS IN WHICH DNAPL WAS OBSERVED
- R.I. SOIL BORING–TOTAL AROMATIC HYDROCARBONS IN SHALLOW ZONE SOIL SAMPLE >10,000 mg/kg OR TOTAL PAH IN SHALLOW ZONE SOIL SAMPLE >1,000 mg/kg
- ELEVATION CONTOURS, TOP OF CONFINING UNIT (FEET ABOVE MEAN SEA LEVEL) C.I.= 2'
- LOCATION OF FORMER PLANT PROCESS AREAS

0 300 600 FEET

REV #	DATE	DESCRIPTION	APPD
1			
2			
3			

REFERENCE: KEYSTONE ENVIRONMENTAL RESOURCES, INC., FINAL REPORT REMEDIAL INVESTIGATION KOPPERS COMPANY, INC. SOUTH CAVALCADE SITE, HOUSTON, TEXAS, JULY 1988, FIGURE 4-6.

KEY ENVIRONMENTAL, INC.

ISSUE DATE:

ROSELYN FARMS INDUSTRIAL PARK 1200 ARCH ST., SUITE 200 CARNEGIE, PA 15106

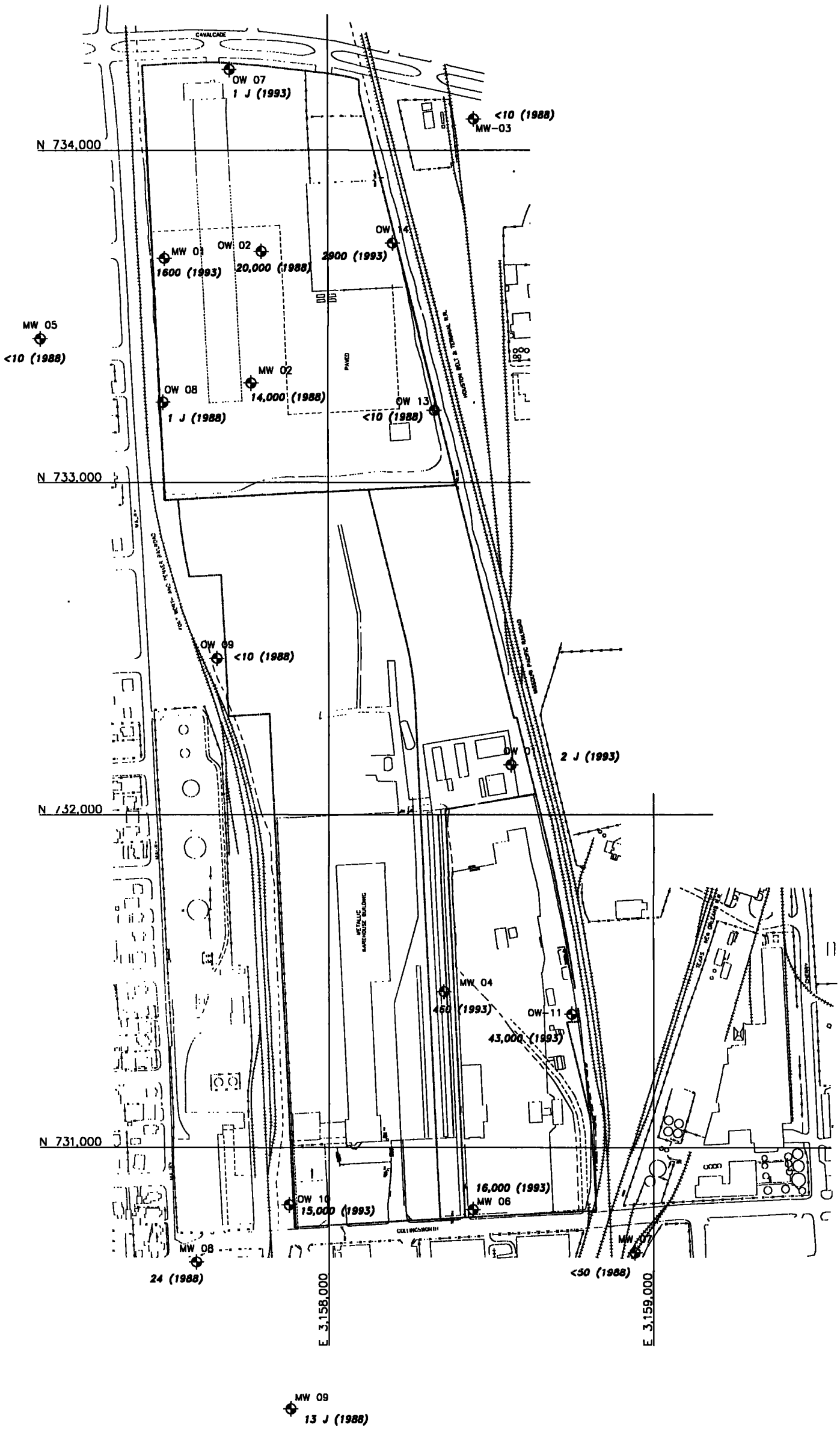
BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/22/97	KEY ENVIRONMENTAL INCORPORATED	
CHKD: JSZ	DATE: 01/22/97		
APPD: JSZ	DATE: 01/22/97		
SCALE: AS SHOWN			

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

FORMER PROCESS AREAS AND TOP OF CLAY CONTOUR MAP

DRAWING NUMBER 96116
FIGURE 9



LEGEND:

MW 09	MONITORING WELL LOCATION
13 J (1988)	NAPHTHALENE CONCENTRATION ug/L (YEAR OF SAMPLE) (J = ESTIMATED CONCENTRATION)

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/27/97	KEY ENVIRONMENTAL INCORPORATED	
CHKD: JSZ	DATE: 01/27/97		
APPD: JSZ	DATE: 01/27/97		
SCALE: AS SHOWN			

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

NAPHTHALENE DISTRIBUTION IN SHALLOW GROUNDWATER

DRAWING NUMBER 96118
FIGURE 10

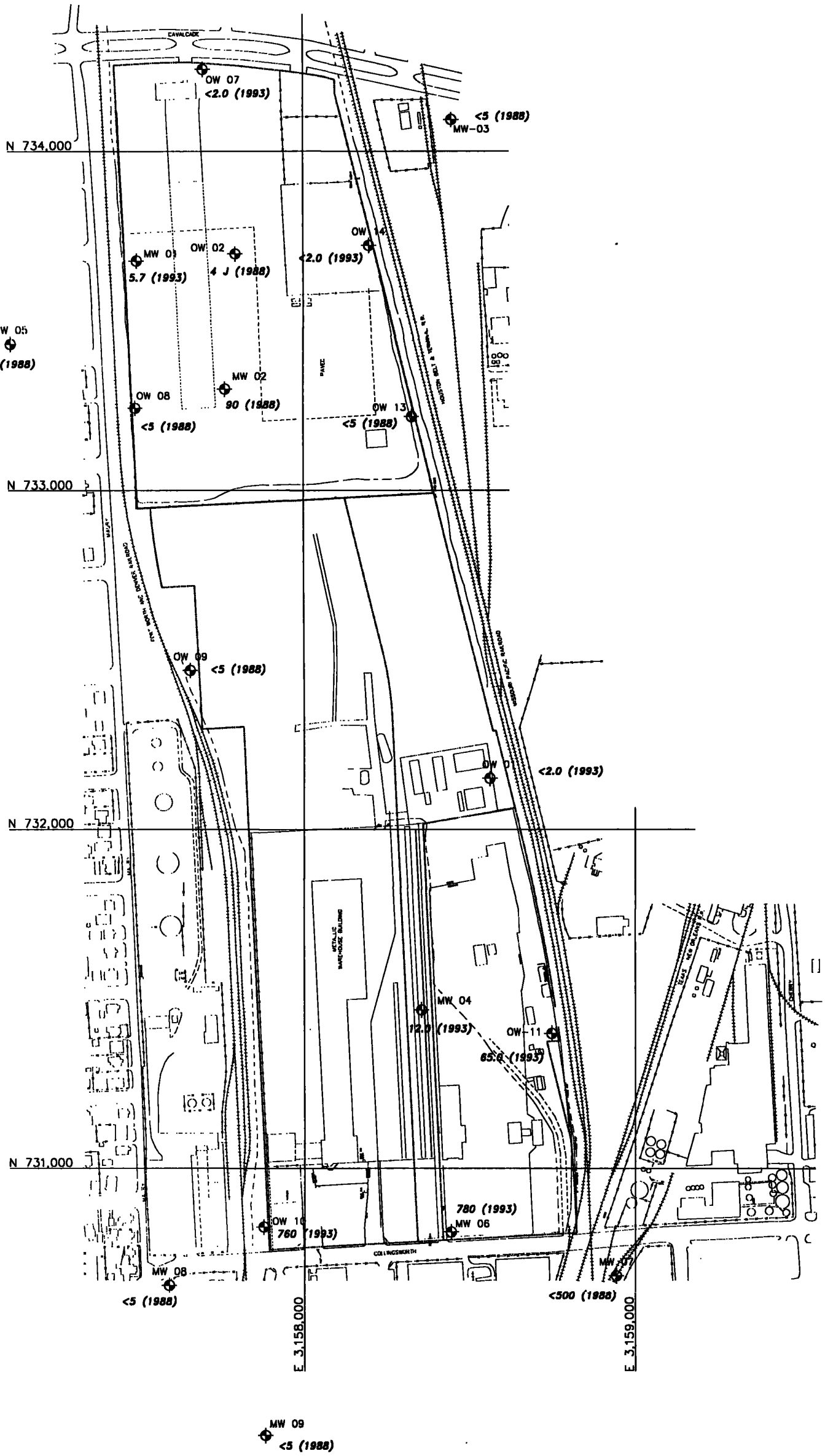
REV #	DATE	DESCRIPTION	APPD
1			
2			
3			

KEY ENVIRONMENTAL, INC.
ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

ISSUE DATE:

000548

EDITED BY: | DATE: | TIME: | EDITING TIME: | DRAWING NAME: C:\CAVALCAD\98118\FIG-11B.DWG



LEGEND:

MW 09 — MONITORING WELL LOCATION

<5 (1988) — BENZENE CONCENTRATION ug/L (YEAR OF SAMPLE)
(J = ESTIMATED CONCENTRATION)

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/27/97	KEY ENVIRONMENTAL INCORPORATED
CHKD: JSZ	DATE: 01/27/97	
APPD: JSZ	DATE: 01/27/97	
SCALE: AS SHOWN		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

BENZENE DISTRIBUTION IN SHALLOW GROUNDWATER

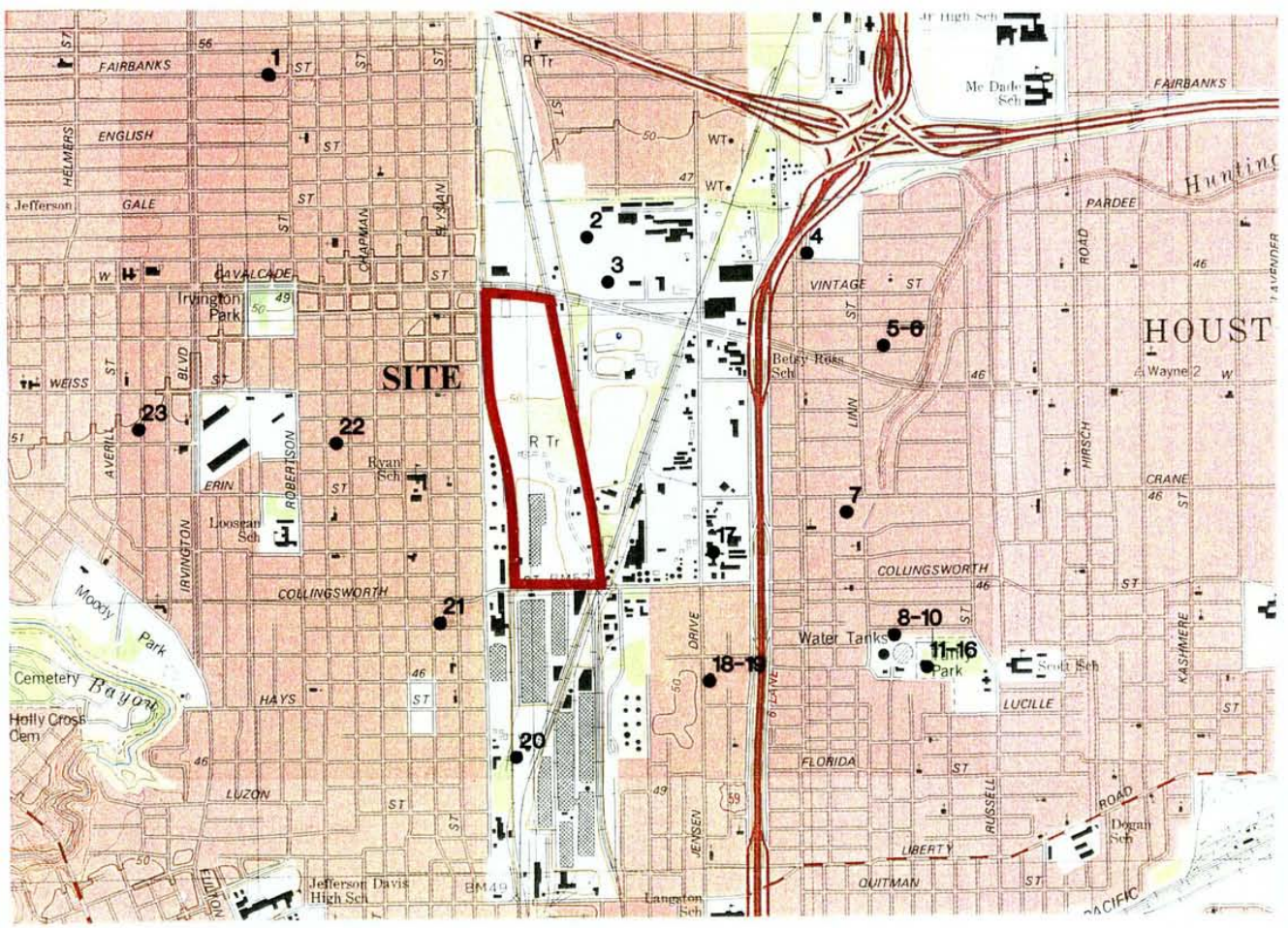
DRAWING NUMBER 98118
FIGURE 11

REV #	DATE	DESCRIPTION	APPD

KEY ENVIRONMENTAL, INC.
ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

ISSUE DATE:

WATER WELL DATA				
NO.	OWNER	DEPTH	DIAMETER (IN.)	STATUS
1	D. ADAMS	175'	6.75"	DOMESTIC
2	T.V. TRAN	363'	6.75"	DOMESTIC
3	C.G. VAUGHN	292'	6.75"	DOMESTC
4	CITY OF HOUSTON	2080'	24"	PUBLIC SUPPLY
5	GOODWILL INDUSTRIES	561'	7.875"	PUBLIC SUPPLY
6	RAINBO BAKERY	345'	6.75"	DOMESTIC
7	CITY OF HOUSTON	1993'	24"	PUBLIC SUPPLY
8	HGCSD	1033'	7.875"	TEST WELL
9	HGCSD	487'	7.875"	TEST WELL
10	HGCSD	299'	7.875"	TEST WELL
11	HGCSD	1596'	4.5"	UNUSED
12	HGCSD	487'	4.5"	UNUSED
13	HGCSD	1035'	4.5"	UNUSED
14	HGCSD	298'	4.5"	UNUSED
15	HGCSD	2170'	5.5"	UNUSED
16	CITY OF HOUSTON	1291'	21.5"	ABANDONED
17	HUNT FOODS	782'	14"	INDUSTRIAL
18	M. AUGUSTINE	61'	4.5"	DOMESTIC
19	M&N WELL SERVICE	346'	6.75"	DOMESTIC
20	HOUSTON INTL. TELEPORT	80'	10"	PUBLIC SUPPLY
21	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN
22	KENT WONG	502'	6.5"	INDUSTRIAL
23	HENRY BAKER	378'	6.5"	DOMESTIC



TEXAS

N

QUADRANGLE LOCATION

● WATER WELL LOCATION

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 10/31/96	KEY ENVIRONMENTAL INCORPORATED
CHKD: JSZ	DATE: 10/31/96	
APPD: JSZ	DATE: 10/31/96	
SCALE: 1" = 2000'		

SOUTH CAVALCADE SUPERFUND SITE
BAEAZER EAST, INC.
HOUSTON, TEXAS

REFERENCE: ENVIRO/SEARCH, AUGUST 1996.

KEY ENVIRONMENTAL, INC.
ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

ISSUE DATE:

WELL INVENTORY MAP

DRAWING NUMBER
96118
FIGURE 12

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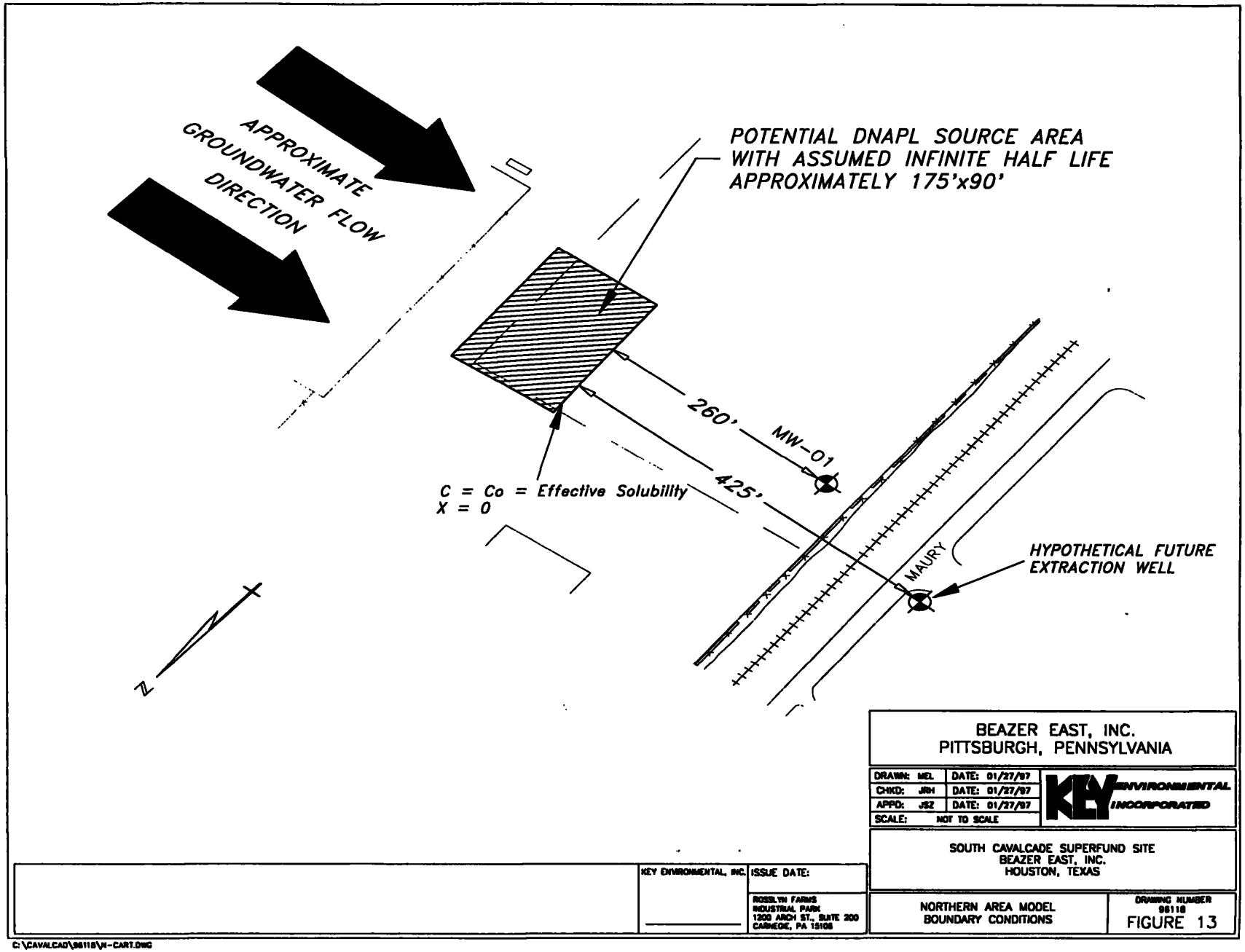


BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/27/97	KEY ENVIRONMENTAL INCORPORATED
CHKD: JRH	DATE: 01/27/97	
APPD: JSZ	DATE: 01/27/97	
SCALE: NOT TO SCALE		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

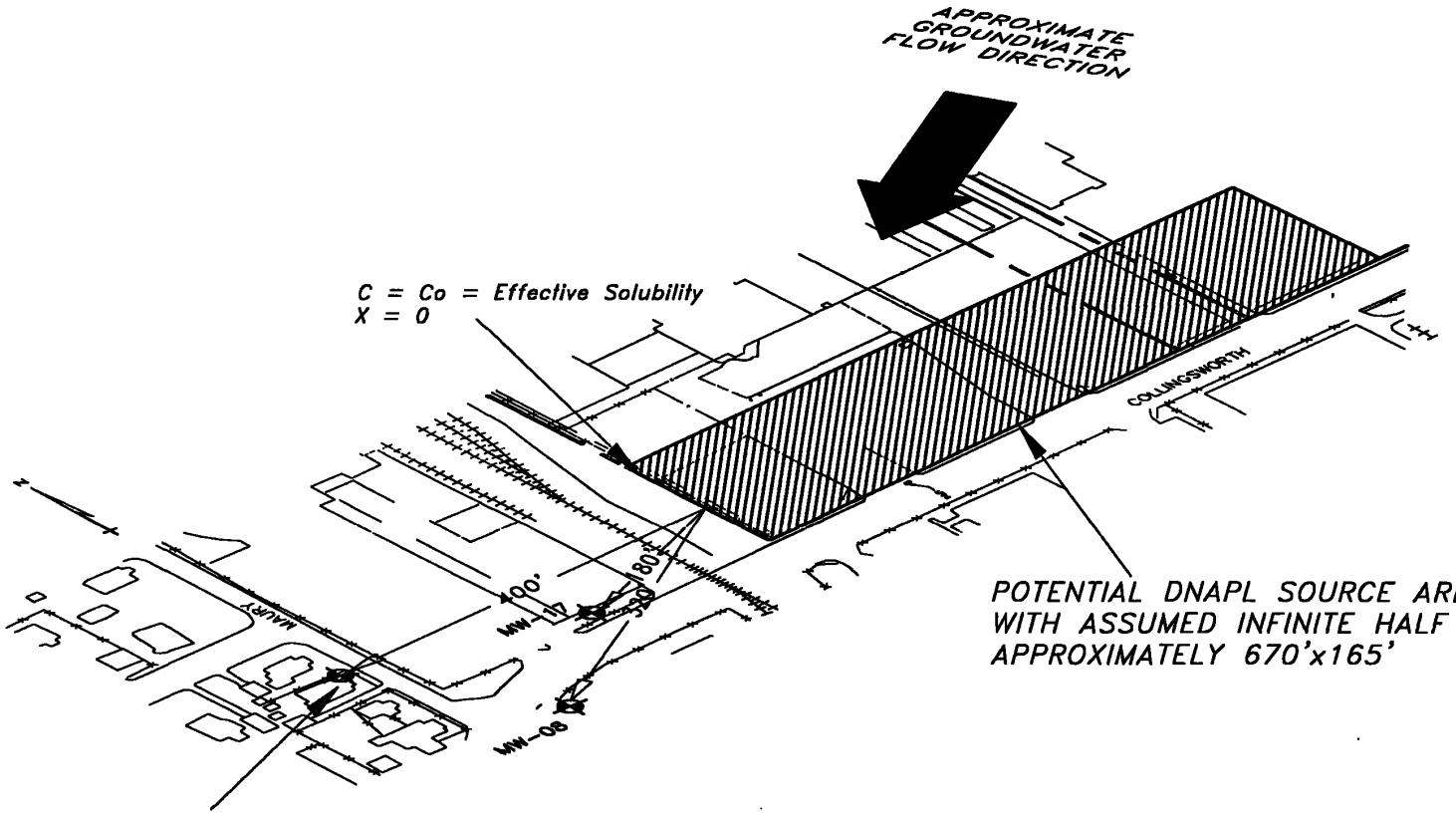
NORTHERN AREA MODEL BOUNDARY CONDITIONS

DRAWING NUMBER 96118
FIGURE 13

KEY ENVIRONMENTAL, INC.
ISSUE DATE:

ROSSLYN FARMS INDUSTRIAL PARK
1300 ARCH ST., SUITE 200
CARNEGIE, PA 15106

C:\CAVALCAD\96118\N-CART.DWG



BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/27/97	KEY ENVIRONMENTAL INCORPORATED
CHKD: JRH	DATE: 01/27/97	
APPD: JSZ	DATE: 01/27/97	
SCALE: NOT TO SCALE		

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

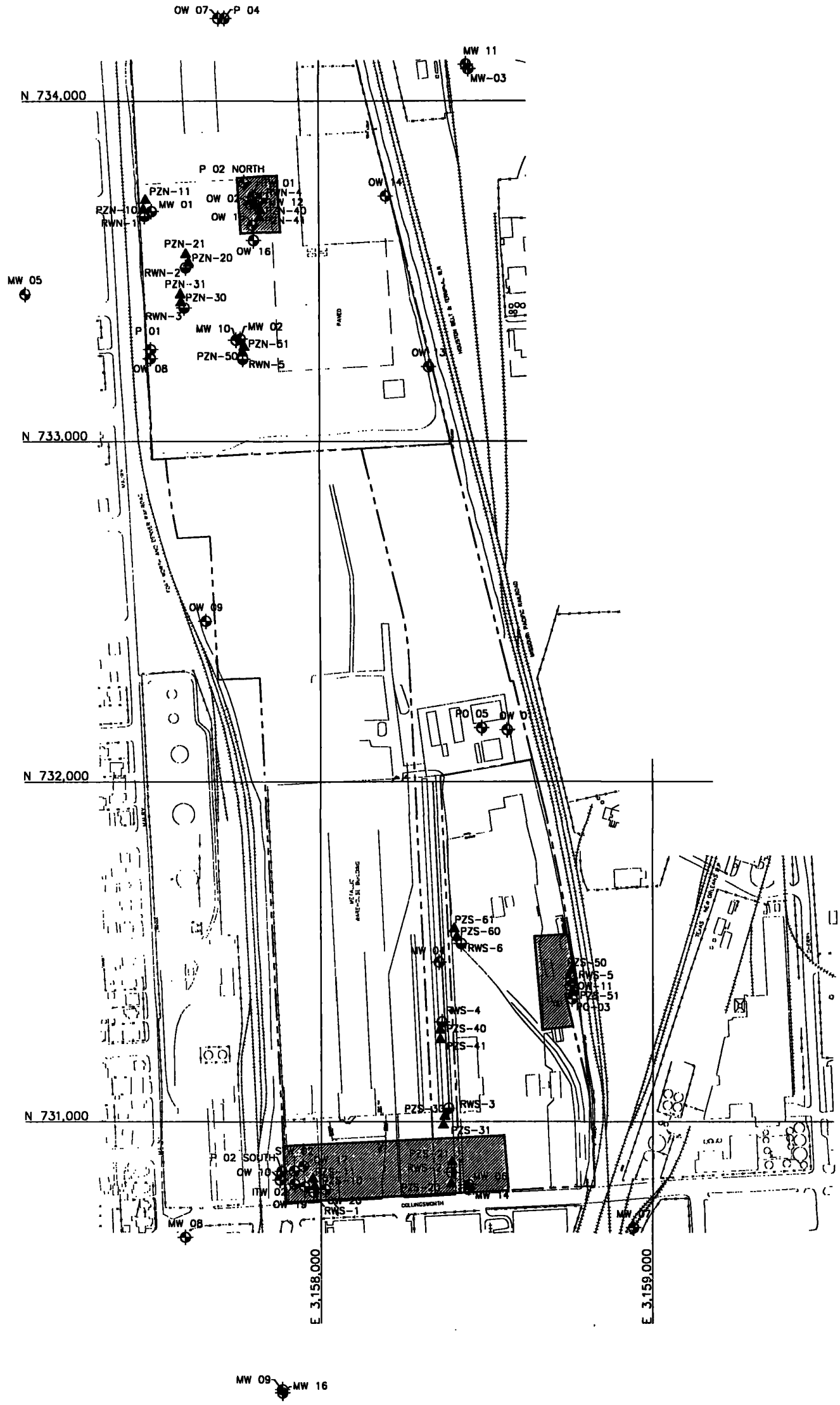
SOUTHERN AREA MODEL
BOUNDARY CONDITIONS

DRAWING NUMBER 96118
FIGURE 14

KEY ENVIRONMENTAL, INC.
ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

ISSUE DATE:

C:\CAVALCAD\96118\S-CART.DWG



LEGEND:

- GROUNDWATER EXTRACTION WELL (FOR HYDRAULIC CONTAINMENT)
- DNAPL AND GROUNDWATER EXTRACTION WELL (FOR HYDRAULIC CONTAINMENT AND SOURCE CONTROL)
- DNAPL RECOVERY WELL LOCATION (FOR SOURCE CONTROL)
- PIEZOMETER LOCATION
- PREVIOUSLY INSTALLED WELL/PIEZOMETER
- POTENTIAL DNAPL RECOVERY AREA

0 300 600 FEET

BEAZER EAST, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN: MEL	DATE: 01/22/97	KEY ENVIRONMENTAL INCORPORATED	
CHKD: JSZ	DATE: 01/22/97		
APPD: JSZ	DATE: 01/22/97		
SCALE: AS SHOWN			

SOUTH CAVALCADE SUPERFUND SITE
BEAZER EAST, INC.
HOUSTON, TEXAS

REV #	DATE	DESCRIPTION	APPD
1			
2			
3			

KEY ENVIRONMENTAL, INC.
ISSUE DATE:
ROSSLYN FARMS INDUSTRIAL PARK
1200 ARCH ST., SUITE 200
CARNEGIE, PA 15106

POTENTIAL DNAPL RECOVERY AREAS

DRAWING NUMBER 96118
FIGURE 15

APPENDIX A

REMEDIAL INVESTIGATION GROUNDWATER ANALYTICAL DATA

KEY ENVIRONMENTAL INCORPORATED

APPENDIX A

REMEDIAL INVESTIGATION GROUNDWATER ANALYTICAL DATA

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW01-001	MW01-002	MW02-001	MW02-002	MW03-001	MW03-002	MW04-001	MW04-002
Zone	S	S	S	S	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	Q	Q	Q	Q	V	Q	V	Q
PHENOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BIS(2-CHLOROETHYL)ETHER	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2-CHLOROPHENOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
1,3-DICHLOROBENZENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
1,4-DICHLOROBENZENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BENZYL ALCOHOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
1,2-DICHLOROBENZENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2-METHYLPHENOL	110 J	130	31 J	37 J	10 U	10 U	50 U	10 U
BIS(2-CHLOROISOPROPYL)ETHER	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
4-METHYLPHENOL	64 J	95	200 U	100 U	10 U	10 U	50 U	10 U
N-NITROSODIPROPYLAMINE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
HEXACHLOROETHANE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
NITROBENZENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
ISOPHORONE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2-NITROPHENOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2,4-DIMETHYLPHENOL	550	620	34 J	36 J	10 U	10 U	50 U	10 U
BENZOIC ACID	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
BIS(2-CHLOROETHOXY)METHANE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2,4-DICHLOROPHENOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
1,2,4-TRICHLOROBENZENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
NAPHTHALENE	3100	3400	11000	14000	10 U	10 U	540	280
4-CHLOROANILINE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
HEXACHLOROBUTADIENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
P-CHLORO-M-CRESOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2-METHYLNAPHTHALENE	110 J	170	530	560	10 U	10 U	7 J	7 J
HEXACHLOROCYCLOPENTADIENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2,4,6-TRICHLOROPHENOL	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2,4,5-TRICHLOROPHENOL	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
2-CHLORONAPHTHALENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2-NITROANILINE	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
DIMETHYL PHTHALATE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
ACENAPHTHYLENE	400 U	9 J	200 U	100 U	10 U	10 U	50 U	10 U
3-NITROANILINE	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
ACENAPHTHENE	110 J	170	540	460	10 U	10 U	150	79
2,4-DINITROPHENOL	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
4-NITROPHENOL	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
DIBENZOFURAN	65 J	88	370	340	10 U	10 U	77	46
2,4-DINITROTOLUENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
2,6-DINITROTOLUENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
DIETHYL PHTHALATE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
4-CHLOROPHENYL PHENYL ETHER	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
FLUORENE	47 J	64	220	200	10 U	10 U	84	55
4-NITROANILINE	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
4,6-DINITRO-2-METHYLPHENOL	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
N-NITROSODIPHENYLAMINE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
4-BROMOPHENYL PHENYL ETHER	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
HEXACHLOROBENZENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
PENTACHLOROPHENOL	2000 U	250 U	1000 U	500 U	50 U	50 U	250 U	50 U
PHENANTHRENE	28 J	50	320	300	10 U	10 U	21 J	11
ANTHRACENE	400 U	50 U	41 J	39 J	10 U	10 U	8 J	6 J
DI-N-BUTYL PHTHALATE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
FLUORANTHENE	400 U	50 U	45 J	55 J	10 U	10 U	50 U	6 J
PYRENE	400 U	50 U	34 J	46 J	10 U	10 U	50 U	3 J
BUTYL BENZYL PHTHALATE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
3,3'-DICHLOROBENZIDINE	800 U	100 U	400 U	200 U	20 U	20 U	100 U	20 U
BENZO(A)ANTHRACENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BIS(2-ETHYLHEXYL)PHTHALATE	400 U	50 U	200 U	100 U	10 U	17	50 U	10 U
CHRYSENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
DI-N-OCTYL PHTHALATE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BENZO(B)FLUORANTHENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BENZO(K)FLUORANTHENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BENZO(A)PYRENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
INDENO(1,2,3-CD)PYRENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
DIBENZO(AH)ANTHRACENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U
BENZO(GHI)PERYLENE	400 U	50 U	200 U	100 U	10 U	10 U	50 U	10 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW05-001	MW06-001	MW06-002	MW07-001	MW07-002	MW08-001	MW08-002	MW09-001
Zone	S	S	S	S	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	Q,V	Q	Q	Q	Q	Q,V	V	V
PHENOL	10 U	40000 U	470	10 U	50 U	10 U	20 U	40 U
BIS(2-CHLOROETHYL)ETHER	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2-CHLOROPHENOL	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
1,3-DICHLOROBENZENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
1,4-DICHLOROBENZENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
BENZYL ALCOHOL	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
1,2-DICHLOROBENZENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2-METHYLPHENOL	10 U	40000 U	1400	10 U	50 U	10 U	20 U	40 U
BIS(2-CHLOROISOPROPYL)ETHER	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
4-METHYLPHENOL	10 U	40000 U	280	10 U	50 U	10 U	20 U	40 U
N-NITROSODIPROPYLAMINE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
HEXACHLOROETHANE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
NITROBENZENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
ISOPHORONE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2-NITROPHENOL	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2,4-DIMETHYLPHENOL	10 U	7100 J	100 U	10 U	50 U	10 U	20 U	40 U
BENZOIC ACID	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
BIS(2-CHLOROETHOXY)METHANE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2,4-DICHLOROPHENOL	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
1,2,4-TRICHLOROBENZENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
NAPHTHALENE	10 U	820000	35000	10 U	50 U	24	2 J	40 U
4-CHLOROANILINE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
HEXACHLOROBUTADIENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
P-CHLORO-M-CRESOL	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2-METHYLNAPHTHALENE	10 U	130000	32000	10 U	50 U	7 J	20 U	40 U
HEXACHLOROCYCLOPENTADIENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2,4,6-TRICHLOROPHENOL	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2,4,5-TRICHLOROPHENOL	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
2-CHLORONAPHTHALENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2-NITROANILINE	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
DIMETHYL PHTHALATE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
ACENAPHTHYLENE	10 U	7300 J	610	10 U	50 U	10 U	20 U	40 U
3-NITROANILINE	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
ACENAPHTHENE	10 U	210000	6100	10 U	50 U	22	12 J	40 U
2,4-DINITROPHENOL	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
4-NITROPHENOL	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
DIBENZOFURAN	10 U	140000	4800	10 U	50 U	20	9 J	40 U
2,4-DINITROTOLUENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
2,6-DINITROTOLUENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
DIETHYL PHTHALATE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
4-CHLOROPHENYL PHENYL ETHER	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
FLUORENE	10 U	170000	5300	10 U	50 U	20	4 J	40 U
4-NITROANILINE	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
4,6-DINITRO-2-METHYLPHENOL	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
N-NITROSODIPHENYLAMINE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
4-BROMOPHENYL PHENYL ETHER	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
HEXACHLOROBENZENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
PENTACHLOROPHENOL	50 U	200000 U	500 U	50 U	250 U	50 U	100 U	200 U
PHENANTHRENE	10 U	480000	18000	10 U	50 U	57	25	40 U
ANTHRACENE	10 U	70000	3200	10 U	50 U	7 J	7 J	40 U
DI-N-BUTYL PHTHALATE	21	40000 U	100 U	10 U	50 U	39	7 J	40 U
FLUORANTHENE	10 U	200000	9400	10 U	50 U	19	15 J	40 U
PYRENE	10 U	160000	6500	10 U	50 U	13	15 J	40 U
BUTYL BENZYL PHTHALATE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
3,3'-DICHLOROBENZIDINE	20 U	80000 U	200 U	20 U	100 U	20 U	40 U	80 U
BENZO(A)ANTHRACENE	10 U	31000 J	2600	10 U	50 U	10 U	20 U	40 U
BIS(2-ETHYLHEXYL)PHTHALATE	10 U	40000 U	100 U	10 U	50 U	10 U	44	40 U
CHRYSENE	10 U	31000 J	1600	10 U	50 U	10 U	20 U	40 U
DI-N-OCTYL PHTHALATE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
BENZO(B)FLUORANTHENE	10 U	9000 J	1200	10 U	50 U	10 U	20 U	40 U
BENZO(K)FLUORANTHENE	10 U	12000 J	100 U	10 U	50 U	10 U	20 U	40 U
BENZO(A)PYRENE	10 U	40000 U	570	10 U	50 U	10 U	20 U	40 U
INDENO(1,2,3-CD)PYRENE	10 U	40000 U	120	10 U	50 U	10 U	20 U	40 U
DIBENZO(AH)ANTHRACENE	10 U	40000 U	100 U	10 U	50 U	10 U	20 U	40 U
BENZO(GHI)PERYLENE	10 U	40000 U	100	10 U	50 U	10 U	20 U	40 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW03-002	MW10-001	MW10-002	MW11-001	MW11-002	MW12-001	MW12-002	MW14-001
Zone	S	S	S	S	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	V Q	V Q	V Q	V Q	V Q	V Q	V Q	V Q
PHENOL	50 U	200 U	10 U	10 U	20 U	140 J	31	20000 U
BIS(2-CHLOROETHYL)ETHER	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2-CHLOROPHENOL	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
1,3-DICHLOROBENZENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
1,4-DICHLOROBENZENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
BENZYL ALCOHOL	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
1,2-DICHLOROBENZENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2-METHYLPHENOL	50 U	200 U	10 U	10 U	20 U	450	80	3800 J
BIS(2-CHLOROISOPROPYL)ETHER	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
4-METHYLPHENOL	50 U	200 U	10 U	10 U	20 U	720	160	8500 J
N-NITROSODIPROPYLAMINE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
HEXACHLOROETHANE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
NITROBENZENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
ISOPHORONE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2-NITROPHENOL	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2,4-DIMETHYLPHENOL	50 U	200 U	10 U	10 U	20 U	1400	170	5500 J
BENZOIC ACID	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
BIS(2-CHLOROETHOXY)METHANE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2,4-DICHLOROPHENOL	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
1,2,4-TRICHLOROBENZENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
NAPHTHALENE	13 J	3400	690	10 U	20 U	7400	7710	340000
4-CHLOROANILINE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
HEXACHLOROBUTADIENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
P-CHLORO-M-CRESOL	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2-METHYLNAPHTHALENE	50 U	160 J	100	10 U	20 U	570	250	55000
HEXACHLOROCYCLOPENTADIENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2,4,6-TRICHLOROPHENOL	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2,4,5-TRICHLOROPHENOL	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
2-CHLORONAPHTHALENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2-NITROANILINE	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
DIMETHYL PHTHALATE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
ACENAPHTHYLENE	50 U	200 U	6 J	10 U	20 U	11 J	6 J	2200 J
3-NITROANILINE	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
ACENAPHTHENE	50 U	680	240	10 U	20 U	650	390	82000
2,4-DINITROPHENOL	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
4-NITROPHENOL	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
DIBENZOFURAN	50 U	340	140	10 U	20 U	410	220	56000
2,4-DINITROTOLUENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
2,6-DINITROTOLUENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
DIETHYL PHTHALATE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
4-CHLOROPHENYL PHENYL ETHER	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
FLUORENE	50 U	210	110	10 U	20 U	310	160	67000
4-NITROANILINE	250 U	1000 U	120	50 U	100 U	1000 U	100 U	100000 U
4,6-DINITRO-2-METHYLPHENOL	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
N-NITROSODIPHENYLAMINE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
4-BROMOPHENYL PHENYL ETHER	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
HEXACHLOROBENZENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
PENTACHLOROPHENOL	250 U	1000 U	50 U	50 U	100 U	1000 U	100 U	100000 U
PHENANTHRENE	50 U	410	180	1 J	20 U	680	370	200000
ANTHRACENE	50 U	50 J	27	10 U	20 U	96 J	31	29000
DI-N-BUTYL PHTHALATE	50 U	200 U	10 U	1 J	20 U	200 U	20 U	20000 U
FLUORANTHENE	50 U	56 J	47	10 U	20 U	200	93	83000
PYRENE	50 U	41 J	42	10 U	20 U	166 J	94	66000
BUTYL BENZYL PHTHALATE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
3,3'-DICHLOROBENZIDINE	100 U	400 U	20 U	20 U	40 U	400 U	40 U	40000 U
BENZO(A)ANTHRACENE	50 U	200 U	9 J	10 U	20 U	28 J	15 J	13000 J
BIS(2-ETHYLHEXYL)PHTHALATE	50 U	200 U	10 U	10	20 U	200 U	20 U	20000 U
CHRYSENE	50 U	200 U	8 J	10 U	20 U	26 J	13 J	13000 J
DI-N-OCTYL PHTHALATE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
BENZO(B)FLUORANTHENE	50 U	200 U	10 U	10 U	20 U	200 U	10 J	8300 J
BENZO(K)FLUORANTHENE	50 U	200 U	4 J	10 U	20 U	200 U	20 U	20000 U
BENZO(A)PYRENE	50 U	200 U	10 U	10 U	20 U	200 U	6 J	20000 U
INDENO(1,2,3-CD)PYRENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
DIBENZO(AH)ANTHRACENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U
BENZO(GHI)PERYLENE	50 U	200 U	10 U	10 U	20 U	200 U	20 U	20000 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW14-002	MW16-001	MW16-002	MW23-001	P01-001	P01-002	P02-001	P02-002
Zone	S	S	S	S	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	Q	V	V	V	V	V	Q	V
PHENOL	1500	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BIS(2-CHLOROETHYL)ETHER	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2-CHLOROPHENOL	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
1,3-DICHLOROBENZENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
1,4-DICHLOROBENZENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BENZYL ALCOHOL	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
1,2-DICHLOROBENZENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2-METHYLPHENOL	5400	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BIS(2-CHLOROISOPROPYL)ETHER	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
4-METHYLPHENOL	11000	20 U	20 U	10 U	10 U	20 U	200 U	10 U
N-NITROSODIPROPYLAMINE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
HEXACHLOROETHANE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
NITROBENZENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
ISOPHORONE	800 U	20 U	20 U	10 U	1 J	20 U	200 U	10 U
2-NITROPHENOL	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2,4-DIMETHYLPHENOL	7800	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BENZOIC ACID	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
BIS(2-CHLOROETHOXY)METHANE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2,4-DICHLOROPHENOL	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
1,2,4-TRICHLOROBENZENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
NAPHTHALENE	70000	20 U	20 U	10 U	10 U	20 U	6100	5200
4-CHLOROANILINE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
HEXACHLOROBUTADIENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
P-CHLORO-M-CRESOL	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2-METHYLNAPHTHALENE	8900	20 U	20 U	10 U	10 U	20 U	400	10 U
HEXACHLOROCYCLOPENTADIENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2,4,6-TRICHLOROPHENOL	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2,4,5-TRICHLOROPHENOL	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
2-CHLORONAPHTHALENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2-NITROANILINE	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
DIMETHYL PHTHALATE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
ACENAPHTHYLENE	310 J	20 U	20 U	10 U	10 U	20 U	17 J	7 J
3-NITROANILINE	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	10 U
ACENAPHTHENE	8400	20 U	20 U	20 U	10 U	20 U	1200	490
2,4-DINITROPHENOL	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
4-NITROPHENOL	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
DIBENZOFURAN	5700	20 U	20 U	10 U	10 U	20 U	620	10 U
2,4-DINITROTOLUENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
2,6-DINITROTOLUENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
DIETHYL PHTHALATE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
4-CHLOROPHENYL PHENYL ETHER	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
FLUORENE	6100	20 U	20 U	10 U	10 U	20 U	440	160
4-NITROANILINE	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
4,6-DINITRO-2-METHYLPHENOL	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
N-NITROSODIPHENYLAMINE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
4-BROMOPHENYL PHENYL ETHER	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
HEXACHLOROBENZENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
PENTACHLOROPHENOL	4000 U	100 U	100 U	50 U	50 U	100 U	1000 U	50 U
PHENANTHRENE	18000	20 U	20 U	10 U	10 U	20 U	990	340
ANTHRACENE	2300	20 U	20 U	10 U	10 U	20 U	110 J	33
DI-N-BUTYL PHTHALATE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
FLUORANTHENE	6900	20 U	20 U	10 U	10 U	20 U	130 J	31
PYRENE	4300	20 U	20 U	10 U	10 U	20 U	140 J	20
BUTYL BENZYL PHTHALATE	800 U	20 U	43	10 U	10 U	20 U	200 U	10 U
3,3'-DICHLOROBENZIDINE	1600 U	40 U	40 U	20 U	20 U	40 U	400 U	20 U
BENZO(A)ANTHRACENE	1200	20 U	20 U	10 U	10 U	20 U	200 U	3 J
BIS(2-ETHYLHEXYL)PHTHALATE	800 U	20 U	20 U	45	19	20 U	200 U	3 J
CHRYSENE	1100	20 U	20 U	10 U	10 U	20 U	200 U	3 J
DI-N-OCTYL PHTHALATE	800 U	20 U	20 U	75	10 U	20 U	200 U	10 U
BENZO(B)FLUORANTHENE	950	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BENZO(K)FLUORANTHENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BENZO(A)PYRENE	480 J	20 U	20 U	10 U	10 U	20 U	200 U	10 U
INDENO(1,2,3-CD)PYRENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
DIBENZO(AH)ANTHRACENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U
BENZO(GHI)PERYLENE	800 U	20 U	20 U	10 U	10 U	20 U	200 U	10 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	P03-001	P03-002	P04-001	P04-002	P05-001	P05-002	OW01-001	OW01-002
Zone	S	S	S	S	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	Q	Q	V	V	Q	V	V	Q
PHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	35 J	35 J
BIS(2-CHLOROETHYL)ETHER	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2-CHLOROPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
1,3-DICHLOROBENZENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
1,4-DICHLOROBENZENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
BENZYL ALCOHOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
1,2-DICHLOROBENZENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2-METHYLPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
BIS(2-CHLOROISOPROPYL)ETHER	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
4-METHYLPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
N-NITROSODIPROPYLAMINE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
HEXACHLOROETHANE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
NITROBENZENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
ISOPHORONE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2-NITROPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2,4-DIMETHYLPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
BENZOIC ACID	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
BIS(2-CHLOROETHOXY)METHANE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2,4-DICHLOROPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
1,2,4-TRICHLOROBENZENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
NAPHTHALENE	140000	15000	10 U	20 U	2400	20 U	11 J	10 J
4-CHLOROANILINE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
HEXACHLOROBUTADIENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
P-CHLORO-M-CRESOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2-METHYLNAPHTHALENE	19000	500 U	10 U	20 U	220 J	20 U	4 J	100 U
HEXACHLOROCYCLOPENTADIENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2,4,6-TRICHLOROPHENOL	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2,4,5-TRICHLOROPHENOL	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
2-CHLORONAPHTHALENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2-NITROANILINE	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
DIMETHYL PHTHALATE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
ACENAPHTHYLENE	10000 U	500 U	10 U	20 U	400 U	20 U	6 J	6 J
3-NITROANILINE	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
ACENAPHTHENE	26000	1100	10 U	20 U	400	20 U	8 J	100 U
2,4-DINITROPHENOL	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
4-NITROPHENOL	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
DIBENZOFURAN	18000	500 U	10 U	20 U	230 J	20 U	40 U	100 U
2,4-DINITROTOLUENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
2,6-DINITROTOLUENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
DIETHYL PHTHALATE	10000 U	500 U	10 U	20 U	70 J	20 U	40 U	100 U
4-CHLOROPHENYL PHENYL ETHER	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
FLUORENE	19000	730	10 U	20 U	150 J	20 U	12 J	100 U
4-NITROANILINE	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
4,6-DINITRO-2-METHYLPHENOL	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
N-NITROSODIPHENYLAMINE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
4-BROMOPHENYL PHENYL ETHER	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
HEXACHLOROBENZENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
PENTACHLOROPHENOL	50000 U	2500 U	50 U	100 U	2000 U	100 U	200 U	500 U
PHENANTHRENE	58000	2200	10 U	20 U	370 J	20 U	63	26 J
ANTHRACENE	8300 J	310 J	10 U	20 U	34 J	20 U	35 J	18 J
DI-N-BUTYL PHTHALATE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
FLUORANTHENE	26000	850	10 U	20 U	64 J	20 U	52	25 J
PYRENE	19000	630	10 U	20 U	41 J	20 U	40	35 J
BUTYL BENZYL PHTHALATE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
3,3'-DICHLOROBENZIDINE	20000 U	1000 U	20 U	40 U	800 U	40 U	80 U	200 U
BENZO(A)ANTHRACENE	5000 J	180 J	10 U	20 U	400 U	20 U	42	34 J
BIS(2-ETHYLHEXYL)PHTHALATE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
CHRYSENE	4900 J	170 J	10 U	20 U	400 U	20 U	42	40 J
DI-N-OCTYL PHTHALATE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
BENZO(B)FLUORANTHENE	2200 J	150 J	10 U	20 U	400 U	20 U	35 J	62 J
BENZO(K)FLUORANTHENE	2600 J	500 U	10 U	20 U	400 U	20 U	46	100 U
BENZO(A)PYRENE	2600 J	500 U	10 U	20 U	400 U	20 U	38 J	100 U
INDENO(1,2,3-CD)PYRENE	10000 U	500 U	10 U	20 U	400 U	20 U	35 J	27 J
DIBENZO(AH)ANTHRACENE	10000 U	500 U	10 U	20 U	400 U	20 U	40 U	100 U
BENZO(GHI)PERYLENE	10000 U	500 U	10 U	20 U	400 U	20 U	32 J	35 J

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	OW02-001	OW02-002	OW06-001	OW06-002	OW07-001	OW07-002	OW08-001	OW08-002
Zone	S	S	D	D	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	Q	Q	V	Q	V	V	V	V
PHENOL	1000 U	132 J	10 U	20 U	10 U	50 U	10 U	20 U
BIS(2-CHLOROETHYL)ETHER	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2-CHLOROPHENOL	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
1,3-DICHLOROBENZENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
1,4-DICHLOROBENZENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BENZYL ALCOHOL	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
1,2-DICHLOROBENZENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2-METHYLPHENOL	870 J	430 J	10 U	20 U	10 U	50 U	10 U	20 U
BIS(2-CHLOROISOPROPYL)ETHER	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
4-METHYLPHENOL	990 J	390 J	10 U	20 U	10 U	50 U	10 U	20 U
N-NITROSODIPROPYLAMINE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
HEXACHLOROETHANE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
NITROBENZENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
ISOPHORONE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2-NITROPHENOL	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2,4-DIMETHYLPHENOL	4500	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BENZOIC ACID	5000 U	5700	50 U	100 U	50 U	250 U	50 U	100 U
BIS(2-CHLOROETHOXY)METHANE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2,4-DICHLOROPHENOL	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
1,2,4-TRICHLOROBENZENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
NAPHTHALENE	20000	13000	10 U	4 J	10 U	50 U	1 J	20 U
4-CHLOROANILINE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
HEXACHLOROBUTADIENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
P-CHLORO-M-CRESOL	1000 U	500 U	7 J	20 U	10 U	50 U	10 U	20 U
2-METHYLNAPHTHALENE	1200	600	10 U	20 U	10 U	50 U	10 U	20 U
HEXACHLOROCYCLOPENTADIENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2,4,6-TRICHLOROPHENOL	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2,4,5-TRICHLOROPHENOL	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
2-CHLORONAPHTHALENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2-NITROANILINE	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
DIMETHYL PHTHALATE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
ACENAPHTHYLENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
3-NITROANILINE	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
ACENAPHTHENE	770 J	409 J	10 U	20 U	10 U	50 U	10 U	20 U
2,4-DINITROPHENOL	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
4-NITROPHENOL	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
DIBENZOFURAN	450 J	231 J	10 U	20 U	10 U	50 U	10 U	20 U
2,4-DINITROTOLUENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
2,6-DINITROTOLUENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
DIETHYL PHTHALATE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
4-CHLOROPHENYL PHENYL ETHER	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
FLUORENE	350 J	195 J	10 U	20 U	10 U	50 U	10 U	20 U
4-NITROANILINE	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
4,6-DINITRO-2-METHYLPHENOL	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
N-NITROSODIPHENYLAMINE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
4-BROMOPHENYL PHENYL ETHER	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
HEXACHLOROBENZENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
PENTACHLOROPHENOL	5000 U	2500 U	50 U	100 U	50 U	250 U	50 U	100 U
PHENANTHRENE	330 J	189 J	10 U	20 U	10 U	50 U	10 U	20 U
ANTHRACENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
DI-N-BUTYL PHTHALATE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
FLUORANTHENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
PYRENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BUTYL BENZYL PHTHALATE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
3,3'-DICHLOROBENZIDINE	2000 U	1000 U	20 U	40 U	20 U	100 U	20 U	40 U
BENZO(A)ANTHRACENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BIS(2-ETHYLHEXYL)PHTHALATE	1000 U	500 U	10 U	20 U	10 U	50 U	4 J	20 U
CHRYSENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
DI-N-OCTYL PHTHALATE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BENZO(B)FLUORANTHENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BENZO(K)FLUORANTHENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BENZO(A)PYRENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
INDENO(1,2,3-CD)PYRENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
DIBENZO(AH)ANTHRACENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U
BENZO(GHI)PERYLENE	1000 U	500 U	10 U	20 U	10 U	50 U	10 U	20 U

NOTES : (U) Undetected; (J) Present below detection limit; (NR) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	OW09-001	OW09-002	OW10-001	OW10-002	OW11-001	OW11-002	OW13-001	OW13-002
Zone	S	S	S	S	S	S	S	S
SEMIVOLATILE ORGANICS (ug/l)								
Validation Status :	V	V	Q	V,Q	Q	Q	Q	Q,V
PHENOL	10 U	10 U	4000 U	37	500000 U	1000 U	10 U	10 U
BIS(2-CHLOROETHYL)ETHER	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2-CHLOROPHENOL	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
1,3-DICHLOROBENZENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
1,4-DICHLOROBENZENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
BENZYL ALCOHOL	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
1,2-DICHLOROBENZENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2-METHYLPHENOL	10 U	10 U	2000 J	310	500000 U	1000 U	10 U	10 U
BIS(2-CHLOROISOPROPYL)ETHER	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
4-METHYLPHENOL	10 U	10 U	1400 J	140	500000 U	1000 U	10 U	10 U
N-NITROSODIPROPYLAMINE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
HEXACHLOROETHANE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
NITROBENZENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
ISOPHORONE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2-NITROPHENOL	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2,4-DIMETHYLPHENOL	10 U	10 U	2700 J	270	500000 U	1000 U	10 U	10 U
BENZOIC ACID	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
BIS(2-CHLOROETHOXY)METHANE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2,4-DICHLOROPHENOL	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
1,2,4-TRICHLOROBENZENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
NAPHTHALENE	10 U	10 U	66000	8100	7100000	19000	10 U	10 U
4-CHLOROANILINE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
HEXACHLOROBUTADIENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
P-CHLORO-M-CRESOL	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2-METHYLNAPHTHALENE	10 U	10 U	6500	400	1300000	9000 J	10 U	10 U
HEXACHLOROCYCLOPENTADIENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2,4,6-TRICHLOROPHENOL	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2,4,5-TRICHLOROPHENOL	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
2-CHLORONAPHTHALENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2-NITROANILINE	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
DIMETHYL PHTHALATE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
ACENAPHTHYLENE	10 U	10 U	290 J	15	50000 J	1000 U	10 U	10 U
3-NITROANILINE	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
ACENAPHTHENE	10 U	10 U	6100	230	2600000	1200	10 U	10 U
2,4-DINITROPHENOL	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
4-NITROPHENOL	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
DIBENZOFURAN	10 U	10 U	4700	160	1300000	1000 U	10 U	10 U
2,4-DINITROTOLUENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
2,6-DINITROTOLUENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
DIETHYL PHTHALATE	10 U	4 J	4000 U	10 U	500000 U	1000 U	10 U	10 U
4-CHLOROPHENYL PHENYL ETHER	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
FLUORENE	10 U	10 U	4800	160	1800000	680 J	10 U	10 U
4-NITROANILINE	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
4,6-DINITRO-2-METHYLPHENOL	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
N-NITROSODIPHENYLAMINE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
4-BROMOPHENYL PHENYL ETHER	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
HEXACHLOROBENZENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
PENTACHLOROPHENOL	50 U	50 U	20000 U	50 U	2500000 U	5000 U	50 U	50 U
PHENANTHRENE	10 U	10 U	12000	220	4900000	1600	10 U	10 U
ANTHRACENE	10 U	10 U	1700 J	23	550000	280 J	10 U	10 U
DI-N-BUTYL PHTHALATE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
FLUORANTHENE	10 U	10 U	4300	38	2600000	800 J	10 U	10 U
PYRENE	10 U	10 U	3100 J	34	1900000	660 J	10 U	10 U
BUTYL BENZYL PHTHALATE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
3,3'-DICHLOROBENZIDINE	20 U	20 U	8000 U	20 U	1000000 U	2000 U	20 U	20 U
BENZO(A)ANTHRACENE	10 U	10 U	670 J	7 J	500000	1000 U	10 U	10 U
BIS(2-ETHYLHEXYL)PHTHALATE	2 J	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
CHRYSENE	10 U	10 U	620 J	6 J	420000 J	1000 U	10 U	10 U
DI-N-OCTYL PHTHALATE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
BENZO(B)FLUORANTHENE	10 U	10 U	4000 U	5 J	500000 U	1000 U	10 U	10 U
BENZO(K)FLUORANTHENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
BENZO(A)PYRENE	10 U	10 U	4000 U	3 J	170000 J	1000 U	10 U	10 U
INDENO(1,2,3-CD)PYRENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
DIBENZO(AH)ANTHRACENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U
BENZO(GHI)PERYLENE	10 U	10 U	4000 U	10 U	500000 U	1000 U	10 U	10 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	GW14-001	GW14-002	GW02-001	GW02-002
Zone	S	S	D	D
SEMIVOLATILE ORGANICS (ug/l)				
Validation Status :	Q	V	V	V
PHENOL	1000 U	50 U	10 U	10 U
BIS(2-CHLOROETHYL)ETHER	1000 U	50 U	10 U	10 U
2-CHLOROPHENOL	1000 U	50 U	10 U	10 U
1,3-DICHLOROBENZENE	1000 U	50 U	10 U	10 U
1,4-DICHLOROBENZENE	1000 U	50 U	10 U	10 U
BENZYL ALCOHOL	1000 U	50 U	10 U	10 U
1,2-DICHLOROBENZENE	1000 U	50 U	10 U	10 U
2-METHYLPHENOL	1000 U	50 U	10 U	10 U
BIS(2-CHLOROISOPROPYL)ETHER	1000 U	50 U	10 U	10 U
4-METHYLPHENOL	1000 U	50 U	10 U	10 U
N-NITROSODIPROPYLAMINE	1000 U	50 U	10 U	10 U
HEXACHLOROETHANE	1000 U	50 U	10 U	10 U
NITROBENZENE	1000 U	50 U	10 U	10 U
ISOPHORONE	1000 U	50 U	10 U	10 U
2-NITROPHENOL	1000 U	50 U	10 U	10 U
2,4-DIMETHYLPHENOL	1000 U	50 U	10 U	10 U
BENZOIC ACID	5000 U	250 U	50 U	50 U
BIS(2-CHLOROETHOXY)METHANE	1000 U	50 U	10 U	10 U
2,4-DICHLOROPHENOL	1000 U	50 U	10 U	10 U
1,2,4-TRICHLOROBENZENE	1000 U	50 U	10 U	10 U
NAPHTHALENE	8200	2600	10 U	10 U
4-CHLOROANILINE	1000 U	50 U	10 U	10 U
HEXACHLOROBUTADIENE	1000 U	50 U	10 U	10 U
P-CHLORO-M-CRESOL	1000 U	50 U	10 U	10 U
2-METHYLNAPHTHALENE	350 J	130	10 U	10 U
HEXACHLOROCYCLOPENTADIENE	1000 U	50 U	10 U	10 U
2,4,6-TRICHLOROPHENOL	1000 U	50 U	10 U	10 U
2,4,5-TRICHLOROPHENOL	5000 U	250 U	50 U	50 U
2-CHLORONAPHTHALENE	1000 U	50 U	10 U	10 U
2-NITROANILINE	5000 U	250 U	50 U	50 U
DIMETHYL PHTHALATE	1000 U	50 U	10 U	10 U
ACENAPHTHYLENE	1000 U	22 J	10 U	10 U
3-NITROANILINE	5000 U	250 U	50 U	50 U
ACENAPHTHENE	1000	440	10 U	10 U
2,4-DINITROPHENOL	5000 U	250 U	50 U	50 U
4-NITROPHENOL	5000 U	250 U	50 U	50 U
DIBENZOFURAN	600 J	230	10 U	10 U
2,4-DINITROTOLUENE	1000 U	50 U	10 U	10 U
2,6-DINITROTOLUENE	1000 U	50 U	10 U	10 U
DIETHYL PHTHALATE	1000 U	50 U	10 U	10 U
4-CHLOROPHENYL PHENYL ETHER	1000 U	50 U	10 U	10 U
FLUORENE	610 J	230	10 U	10 U
4-NITROANILINE	5000 U	250 U	50 U	50 U
4,6-DINITRO-2-METHYLPHENOL	5000 U	250 U	50 U	50 U
N-NITROSODIPHENYLAMINE	1000 U	50 U	10 U	10 U
4-BROMOPHENYL PHENYL ETHER	1000 U	50 U	10 U	10 U
HEXACHLOROBENZENE	1000 U	50 U	10 U	10 U
PENTACHLOROPHENOL	5000 U	250 U	50 U	50 U
PHENANTHRENE	650 J	180	10 U	10 U
ANTHRACENE	130 J	30 J	10 U	10 U
DI-N-BUTYL PHTHALATE	1000 U	50 U	10 U	10 U
FLUORANTHENE	360 J	52	10 U	10 U
PYRENE	230 J	49 J	10 U	10 U
BUTYL BENZYL PHTHALATE	1000 U	50 U	10 U	10 U
3,3'-DICHLOROBENZIDINE	2000 U	100 U	20 U	20 U
BENZO(A)ANTHRACENE	1000 U	50 U	10 U	10 U
BIS(2-ETHYLHEXYL)PHTHALATE	1000 U	50 U	10 U	10 U
CHRYSENE	1000 U	50 U	10 U	10 U
DI-N-OCTYL PHTHALATE	1000 U	50 U	10 U	10 U
BENZO(B)FLUORANTHENE	1000 U	50 U	10 U	10 U
BENZO(K)FLUORANTHENE	1000 U	50 U	10 U	10 U
BENZO(A)PYRENE	1000 U	50 U	10 U	10 U
INDENO(1,2,3-CD)PYRENE	1000 U	50 U	10 U	10 U
DIBENZO(AH)ANTHRACENE	1000 U	50 U	10 U	10 U
BENZO(GHI)PERYLENE	1000 U	50 U	10 U	10 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not Analyzed; (V) Valid; (I) Invalid; (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CHVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW01-001	MW01-002	MW02-001	MW02-002	MW03-001	MW03-002	MW04-001
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	V	Q	V	Q	V	Q	V
CHLOROMETHANE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
BROMOMETHANE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
VINYL CHLORIDE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
CHLOROETHANE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
METHYLENE CHLORIDE	5 U	5 U	400	5 U	5 U	5 U	180
ACETONE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
CARBON DISULFIDE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
1,1-DICHLOROETHENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
1,1-DICHLOROETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
TRANS-1,2-DICHLOROETHENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
CHLOROFORM	5 U	5 U	100 U	5 U	5 U	5 U	100 U
1,2-DICHLOROETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
2-BUTANONE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
1,1,1-TRICHLOROETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
CARBON TETRACHLORIDE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
VINYL ACETATE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
BROMODICHLOROMETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
1,2-DICHLOROPROPANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
TRANS-1,3-DICHLOROPROPENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
TRICHLOROETHENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
DIBROMOCHLOROMETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
1,1,2-TRICHLOROETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
BENZENE	2 J	15	90	77	5 U	5 U	50 J
CIS-1,3-DICHLOROPROPENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
2-CHLOROETHYLVINYL ETHER	10 U	10 U	200 U	10 U	10 U	10 U	200 U
BROMOFORM	5 U	5 U	100 U	5 U	5 U	5 U	100 U
2-HEXANONE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
4-METHYL-2-PENTANONE	10 U	10 U	200 U	10 U	10 U	10 U	200 U
TETRACHLOROETHENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
1,1,2,2-TETRACHLOROETHANE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
TOLUENE	3 J	34	120	75	5 U	5 U	100 U
CHLOROBENZENE	5 U	5 U	100 U	5 U	5 U	5 U	100 U
ETHYLBENZENE	2 J	21	160	65	5 U	5 U	100 U
STYRENE	5 U	4 J	100 U	6	5 U	5 U	100 U
TOTAL XYLENES	3 J	38	400	110	5 U	5 U	100 U
PESTICIDES/PCB (ug/l)	V	V	V	V	V	V	V
ALPHA-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
BETA-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
DELTA-BHC	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
GAMMA-BHC (LINDANE)	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
HEPTACHLOR	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
ALDRIN	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
HEPTACHLOR EPOXIDE	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
ENDOSULFAN I	0.05 U	0.05 U	0.05 U	0.15	0.05 U	0.05 U	0.05 U
DIELDRIN	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
ENDRIN	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
ENDOSULFAN II	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDD	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
ENDRIN ALDEHYDE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
ENDOSULFAN SULFATE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDT	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
METHOXYCHLOR	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
ENDRIN KETONE	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
CHLORDANE	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
TOXAPHENE	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
AROCLOR-1016	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1221	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1232	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1242	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1248	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1254	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
AROCLOR-1260	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
INORGANICS (ug/l)	Q	V	V	V	Q	V	V
SILVER	10 U	8 U	10 U(Q)	8 U	10 U	8 U	10 U
ARSENIC	61.7	105	20.2	82.5	10 U	12.4	25.3
BERYLLIUM	3 U	14	3 U	11	3 U	3 U	4
CADMIUM	5 U	4 U	5 U(Q)	4 U	5 U	4 U	5 U
CYANIDE	100 U	NA	100 U	NA	100 U	NA	100 U
CHROMIUM	98	160	9 U	108	9 U	37	15
COPPER	41	107	10 U	64	10 U	14 U	10 U
IRON	100000	181000 (Q)	4840	134000 (Q)	1420	18500 (Q)	7510
MERCURY	0.2 U	0.2 U(Q)	0.2 U	0.2 U(Q)	0.2 U	0.2 U(Q)	0.2 U
NICKEL	125	194	42	163	56	52	29 U
NITRATE	NA	NA	NA	100	NA	100	NA
LEAD	80.0	160	19	100	5 U	17	36
ANTIMONY	44 U	48 U(Q)	44 U(Q)	48 U(Q)	44 U	48 U(Q)	44 U
SELENIUM	5 U	5 U	5 U(Q)	5 U	5 U	5 U	5 U
THALLIUM	10 U	10 U	10 U	10 U	10 U	10 U	10 U
ZINC	196	367	37	241	20	42	61

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW01-002	MW05-001	MW06-001	MW06-002	MW07-001	MW07-002	MW08-001
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	NA	V	V	NA	V	NA	V
CHLOROMETHANE		10 U	200 U		10000 U		10 U
BROMOMETHANE		10 U	200 U		10000 U		10 U
VINYL CHLORIDE		10 U	200 U		10000 U		10 U
CHLOROETHANE		10 U	200 U		10000 U		10 U
METHYLENE CHLORIDE		4 J	470		5000 U		5 U
ACETONE		10 U	200 U		5600 J		10 U
CARBON DISULFIDE		5 U	100 U		5000 U		5 U
1,1-DICHLOROETHENE		10 U	100 U		5000 U		10 U
1,1-DICHLOROETHANE		5 U	100 U		5000 U		5 U
TRANS-1,2-DICHLOROETHENE		5 U	100 U		5000 U		5 U
CHLOROFORM		5 U	100 U		5000 U		5 U
1,2-DICHLOROETHANE		5 U	100 U		5000 U		5 U
2-BUTANONE		10 U	200 U		10000 U		10 U
1,1,1-TRICHLOROETHANE		5 U	100 U		5000 U		5 U
CARBON TETRACHLORIDE		5 U	100 U		5000 U		5 U
VINYL ACETATE		10 U	200 U		10000 U		10 U
BROMODICHLOROMETHANE		5 U	100 U		5000 U		5 U
1,2-DICHLOROPROPANE		5 U	100 U		5000 U		5 U
TRANS-1,3-DICHLOROPROPENE		5 U	100 U		5000 U		5 U
TRICHLOROETHENE		5 U	100 U		5000 U		5 U
DIBROMOCHLOROMETHANE		5 U	100 U		5000 U		5 U
1,1,2-TRICHLOROETHANE		5 U	100 U		5000 U		5 U
BENZENE		5 U	930		5000 U		5 U
CIS-1,3-DICHLOROPROPENE		5 U	100 U		5000 U		5 U
2-CHLOROETHYLVINYL ETHER		10 U	200 U		10000 U		10 U
BROMOFORM		5 U	100 U		5000 U		5 U
2-HEXANONE		10 U	200 U		10000 U		10 U
4-METHYL-2-PENTANONE		10 U	200 U		10000 U		10 U
TETRACHLOROETHENE		5 U	100 U		5000 U		5 U
1,1,2,2-TETRACHLOROETHANE		5 U	100 U		5000 U		5 U
TOLUENE		5 U	900		5000 U		5 U
CHLOROBENZENE		5 U	100 U		5000 U		5 U
ETHYLBENZENE		5 U	170		5000 U		5 U
STYRENE		5 U	100 U		5000 U		5 U
TOTAL XYLENES		5 U	680		5000 U		5 U
PESTICIDES/PCB (ug/l)	V	Q	V	V	V	V	Q
ALPHA-BHC	0.05 U	0.005 U	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
BETA-BHC	0.05 U	0.005 U	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
DELTA-BHC	0.05 U	0.005 U	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
GAMMA-BHC (LINDANE)	0.05 U	0.005 U	2.50 J	0.25 U	0.05 U	0.05 U	0.005 U
HEPTACHLOR	0.05 U	0.005 UB	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
ALDRIN	0.05 U	0.005 U	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
HEPTACHLOR EPOXIDE	0.05 U	0.005 U	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
ENDOSULFAN I	0.05 U	0.005 U	2.50 U	0.25 U	0.05 U	0.05 U	0.005 U
DIELDRIN	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
4,4'-DDE	0.10 U	0.010 U	5.00 U	8.1	0.10 U	0.10 U	0.010 U
ENDRIN	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
ENDOSULFAN II	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
4,4'-DDD	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
ENDRIN ALDEHYDE	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
ENDOSULFAN SULFATE	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
4,4'-DDT	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
METHOXYCHLOR	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
ENDRIN KETONE	0.10 U	0.010 U	5.00 U	0.50 U	0.10 U	0.10 U	0.010 U
CHLORDANE	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
TOXAPHENE	1.0 U	0.100 U	50.0 U	5.0 U	1.0 U	1.0 U	0.100 U
AROCLOR-1016	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
AROCLOR-1221	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
AROCLOR-1232	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
AROCLOR-1242	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
AROCLOR-1248	0.50 U	0.050 U	25.00 U	2.50 U	0.50 U	0.50 U	0.050 U
AROCLOR-1254	1.0 U	0.100 U	50.0 U	5.0 U	1.0 U	1.0 U	0.100 U
AROCLOR-1260	1.0 U	0.100 U	50.0 U	5.0 U	1.0 U	1.0 U	0.100 U
INORGANICS (ug/l)	V	V	V	V	V	V	V
SILVER	NA	8 U	50 U(Q)	8 U	10 U(Q)	NA	8 U
ARSENIC	40.0	10 U(Q)	33.4	80	24	55	34.6 (Q)
BERYLLIUM	NA	4 U	15 U	3 U	3 U	NA	4
CADMIUM	NA	5 U	25 U(Q)	4 U	6 (Q)	NA	5 U
CYANIDE	NA	10 U	100 U	NA	100 U	NA	10 U
CHROMIUM	30	111	450	16	9 U	30	185
COPPER	NA	12	75	1340	17	NA	38
IRON	NA	38000	35600	13600 (Q)	5260	NA	78000
MERCURY	NA	0.2 U	0.2 U	0.2 U(Q)	0.2 U	NA	0.2 U
NICKEL	72	127 U	360	318	29 U	85	231
NITRATE	NA	500	NA	100 U	NA	NA	200
LEAD	12	25.8 (Q)	119	5 U	34	27	35.9 (Q)
ANTIMONY	NA	50 U	220 U(Q)	40 U(Q)	44 U(Q)	NA	50 U
SELENIUM	NA	5 U(Q)	25 U(Q)	5 U	5 U(Q)	NA	5 U(Q)
THALLIUM	NA	10 U(Q)	10 U	10 U	10 U	NA	10 U(Q)
ZINC	67	74	685	1180	49	109	180

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep; (B) Detected in Blank.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW08-002	MW09-001	MW09-002	MW10-001	MW10-002	MW11-001	MW11-002
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	NA	V	NA	V	Q	V	Q
CHLOROMETHANE		10 U		50 U	10 U	10 U	10 U
BROMOMETHANE		10 U		50 U	10 U	10 U	10 U
VINYL CHLORIDE		10 U		50 U	10 U	10 U	10 U
CHLOROETHANE		10 U		50 U	10 U	10 U	10 U
METHYLENE CHLORIDE		5 U		25 U	5 U	5 U	5 U
ACETONE		9 J		50 U	10 U	50	10 U
CARBON DISULFIDE		5 U		25 U	5 U	5 U	5 U
1,1-DICHLOROETHENE		5 U		25 U	5 U	5 U	5 U
1,1-DICHLOROETHANE		5 U		25 U	5 U	5 U	5 U
TRANS-1,2-DICHLOROETHENE		5 U		25 U	5 U	5 U	5 U
CHLOROFORM		5 U		25 U	5 U	5 U	5 U
1,2-DICHLOROETHANE		5 U		25 U	5 U	5 U	5 U
2-BUTANONE		10 U		50 U	10 U	10 U	10 U
1,1,1-TRICHLOROETHANE		5 U		25 U	5 U	5 U	5 U
CARBON TETRACHLORIDE		5 U		25 U	5 U	5 U	5 U
VINYL ACETATE		10 U		50 U	10 U	10 U	10 U
BROMODICHLOROMETHANE		5 U		25 U	5 U	5 U	5 U
1,2-DICHLOROPROPANE		5 U		25 U	5 U	5 U	5 U
TRANS-1,3-DICHLOROPROPENE		5 U		25 U	5 U	5 U	5 U
TRICHLOROETHENE		5 U		25 U	5 U	5 U	5 U
DIBROMOCHLOROMETHANE		5 U		25 U	5 U	5 U	5 U
1,1,2-TRICHLOROETHANE		5 U		25 U	5 U	5 U	5 U
BENZENE		5 U		8 J	5 U	5 U	5 U
CIS-1,3-DICHLOROPROPENE		5 U		25 U	5 U	5 U	5 U
2-CHLOROETHYLVINYL ETHER		10 U		50 U	10 U	10 U	10 U
BROMOFORM		5 U		25 U	5 U	5 U	5 U
2-HEXANONE		10 U		50 U	10 U	10 U	10 U
4-METHYL-2-PENTANONE		10 U		50 U	10 U	10 U	10 U
TETRACHLOROETHENE		5 U		25 U	5 U	5 U	5 U
1,1,2,2-TETRACHLOROETHANE		5 U		25 U	5 U	5 U	5 U
TOLUENE		5 U		25 U	5 U	5 U	5 U
CHLOROBENZENE		5 U		25 U	5 U	5 U	5 U
ETHYLBENZENE		5 U		25 U	8	5 U	3 J
STYRENE		5 U		25 U	5 U	5 U	5 U
TOTAL XYLENES		5 U		11 J	5 U	5 U	5 U
PESTICIDES/PCB (ug/l)	NA	V	NA	V	V	V	V
ALPHA-BHC		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
BETA-BHC		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
DELTA-BHC		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
GAMMA-BHC (LINDANE)		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
HEPTACHLOR		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
ALDRIN		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
HEPTACHLOR EPOXIDE		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
ENDOSULFAN I		0.05 U		0.05 U	0.05 U	0.05 U	0.05 U
DIELDRIN		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDE		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
ENDRIN		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
ENDOSULFAN II		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDD		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
ENDRIN ALDEHYDE		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
ENDOSULFAN SULFATE		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
4,4'-DDT		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
METHOXYCHLOR		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
ENDRIN KETONE		0.10 U		0.10 U	0.10 U	0.10 U	0.10 U
CHLORDANE		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
TOXAPHENE		1.0 U		1.0 U	1.0 U	1.0 U	1.0 U
AROCLOR-1016		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1221		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1232		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1242		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1248		0.50 U		0.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1254		1.0 U		1.0 U	1.0 U	1.0 U	1.0 U
AROCLOR-1260		1.0 U		1.0 U	1.0 U	1.0 U	1.0 U
INORGANICS (ug/l)	V	V	V	V	V	Q	V
SILVER	9 U	10 U(Q)	NA	10 U	8 U	10 U	8 U
ARSENIC	10 U	10 U	14	25	48	10 U	12
BERYLLIUM	2 U	3 U	NA	3 U	5	3 U	3 U
CADMIUM	5 U	5 U(Q)	NA	5 U	4 U	5 U	4 U
CYANIDE	NA	100 U	NA	100 U	NA	100 U	NA
CHROMIUM	27	9 U	99	9 U	62	102	29
COPPER	21	11	NA	10 U	21	31	14 U
IRON	NA	3300	NA	2320	44700 (Q)	91900	21900 (Q)
MERCURY	0.2 U	0.2 U	NA	0.2 U	0.2 U(Q)	0.2 U	0.2 U(Q)
NICKEL	35	29 U	53	29 U	70	131	24 U
NITRATE	NA	NA	NA	NA	100 U	NA	NA
LEAD	34	23	233	5 U	30	39	13
ANTIMONY	54 U	44 U(Q)	NA	44 U	48 U(Q)	44 U	48 U(Q)
SELENIUM	5 U	5 U(Q)	NA	5 U	5 U	5 U	5 U
THALLIUM	10 U	10 U	NA	10 U	10 U	10 U	10 U
ZINC	59	67	549	29	75	345	96

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	MW12-001	MW12-002	MW14-001	MW14-002	MW16-001	MW16-002	MW23-001
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	V	NA	V	NA	V	V	V
CHLOROMETHANE	1000 U		1000 U		10 U	10 U	10 U
BROMOMETHANE	1000 U		1000 U		10 U	10 U	10 U
VINYL CHLORIDE	1000 U		1000 U		10 U	10 U	10 U
CHLOROETHANE	1000 U		1000 U		10 U	10 U	10 U
METHYLENE CHLORIDE	500 U		500 U		5 U	5 U	5 U
ACETONE	1000 U		490 J		170	150	10 U
CARBON DISULFIDE	500 U		500 U		5 U	5 U	5 U
1,1-DICHLOROETHENE	500 U		500 U		5 U	5 U	10 U
1,1-DICHLOROETHANE	500 U		500 U		5 U	5 U	5 U
TRANS-1,2-DICHLOROETHENE	500 U		500 U		5 U	5 U	5 U
CHLOROFORM	500 U		500 U		5 U	3 J	5 U
1,2-DICHLOROETHANE	500 U		500 U		5 U	5 U	5 U
2-BUTANONE	1000 U		1000 U		10 U	10 U	10 U
1,1,1-TRICHLOROETHANE	500 U		500 U		5 U	5 U	5 U
CARBON TETRACHLORIDE	500 U		500 U		5 U	5 U	5 U
VINYL ACETATE	1000 U		1000 U		10 U	10 U	10 U
BROMODICHLOROMETHANE	500 U		500 U		5 U	5 U	5 U
1,2-DICHLOROPROPANE	500 U		500 U		5 U	5 U	5 U
TRANS-1,3-DICHLOROPROPENE	500 U		500 U		5 U	5 U	5 U
TRICHLOROETHENE	500 U		500 U		5 U	5 U	5 U
DIBROMOCHLOROMETHANE	500 U		500 U		5 U	5 U	5 U
1,1,2-TRICHLOROETHANE	500 U		500 U		5 U	5 U	5 U
BENZENE	500 U		830		5 U	5 U	5 U
CIS-1,3-DICHLOROPROPENE	500 U		500 U		5 U	5 U	5 U
2-CHLOROETHYLVINYL ETHER	1000 U		1000 U		10 U	10 U	10 U
BROMOFORM	500 U		500 U		5 U	5 U	5 U
2-HEXANONE	1000 U		1000 U		10 U	10 U	10 U
4-METHYL-2-PENTANONE	1000 U		1000 U		10 U	10 U	10 U
TETRACHLOROETHENE	500 U		500 U		5 U	5 U	5 U
1,1,2,2-TETRACHLOROETHANE	500 U		500 U		5 U	5 U	5 U
TOLUENE	500 U		640		5 U	5 U	5 U
CHLOROBENZENE	500 U		500 U		5 U	5 U	5 U
ETHYLBENZENE	500 U		500 U		5 U	5 U	5 U
STYRENE	500 U		500 U		5 U	5 U	5 U
TOTAL XYLENES	500 U		500 U		5 U	5 U	5 U
PESTICIDES/PCB (ug/l)	V	NA	V	V	V	V	V
ALPHA-BHC	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
BETA-BHC	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
DELTA-BHC	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
GAMMA-BHC (LINDANE)	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
HEPTACHLOR	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
ALDRIN	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
HEPTACHLOR EPOXIDE	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
ENDOSULFAN I	0.05 U		2.50 U	0.25 U	0.05 U	0.05 U	0.05 U
DIELDRIN	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
4,4'-DDE	0.10 U		5.00 U	1.7	0.10 U	0.10 U	0.10 U
ENDRIN	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
ENDOSULFAN II	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
4,4'-DDD	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
ENDRIN ALDEHYDE	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
ENDOSULFAN SULFATE	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
4,4'-DDT	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
METHOXYCHLOR	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
ENDRIN KETONE	0.10 U		5.00 U	0.50 U	0.10 U	0.10 U	0.10 U
CHLORDANE	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
TOXAPHENE	1.0 U		50.0 U	5.0 U	1.0 U	1.0 U	1.00 U
AROCLOR-1016	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1221	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1232	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1242	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1248	0.50 U		25.00 U	2.50 U	0.50 U	0.50 U	0.50 U
AROCLOR-1254	1.0 U		50.0 U	5.0 U	1.0 U	1.0 U	1.00 U
AROCLOR-1260	1.0 U		50.0 U	5.0 U	1.0 U	1.0 U	1.00 U
INORGANICS (ug/l)	V	V	V	V	V	V	V
SILVER	10 U(Q)	NA	10 U(Q)	NA	10 U(Q)	8 U	9 U
ARSENIC	29.0	27	50	26	10 U	10 U	5 U
BERYLLIUM	3 U	NA	3 U	NA	3 U	3 U	2 U
CADMIUM	5 U(Q)	NA	5 U(Q)	NA	5 U(Q)	4 U	5 U
CYANIDE	100 U	NA	100 U	NA	100 U	NA	10 U
CHROMIUM	11	73	26	9 U	20	12	8 U
COPPER	11	NA	33	NA	10 U	14 U	16 U
IRON	9620	NA	22100	NA	428	314 (I)	2720
MERCURY	0.2 U	NA	0.2 U	NA	0.2 U	0.2 U	0.2 U
NICKEL	29 U	76	47	29	29 U	24 U	34 U
NITRATE	NA	NA	NA	NA	NA	200	400
LEAD	102	72	67	5 U	7	5 U	4 U
ANTIMONY	44 U(Q)	NA	44 U(Q)	NA	44 U(Q)	48 U	54 U
SELENIUM	5 U(Q)	NA	5 U(Q)	NA	5 U(Q)	5 U	4 U
THALLIUM	10 U	NA	10 U	NA	10 U	10 U	5 U(Q)
ZINC	60	141	75	17 U	24	17 U	10 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid
(NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	P01-001	P01-002	P02-001	P02-002	P03-001	P03-002	P04-001
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	V	NA	V	NA	V	NA	V
CHLOROMETHANE	10 U		200 U		1000 U		10 U
BROMOMETHANE	10 U		200 U		1000 U		10 U
VINYL CHLORIDE	10 U		200 U		1000 U		10 U
CHLOROETHANE	10 U		200 U		1000 U		10 U
METHYLENE CHLORIDE	.5 U		100 U		500 U		5 U
ACETONE	10 U		200 U		1000 J		10 U
CARBON DISULFIDE	5 U		100 U		500 U		5 U
1,1-DICHLOROETHENE	5 U		100 U		500 U		5 U
1,1-DICHLOROETHANE	5 U		100 U		500 U		5 U
TRANS-1,2-DICHLOROETHENE	5 U		100 U		500 U		5 U
CHLOROFORM	5 U		100 U		500 U		5 U
1,2-DICHLOROETHANE	5 U		100 U		500 U		5 U
2-BUTANONE	10 U		200 U		1000 U		10 U
1,1,1-TRICHLOROETHANE	5 U		100 U		500 U		5 U
CARBON TETRACHLORIDE	5 U		100 U		500 U		5 U
VINYL ACETATE	10 U		200 U		1000 U		10 U
BROMODICHLOROMETHANE	5 U		100 U		500 U		5 U
1,2-DICHLOROPROPANE	5 U		100 U		500 U		5 U
TRANS-1,3-DICHLOROPROPENE	5 U		100 U		500 U		5 U
TRICHLOROETHENE	5 U		100 U		500 U		5 U
DIBROMOCHLOROMETHANE	5 U		100 U		500 U		5 U
1,1,2-TRICHLOROETHANE	5 U		100 U		500 U		5 U
BENZENE	5 U		70 J		800		5 U
CIS-1,3-DICHLOROPROPENE	5 U		100 U		500 U		5 U
2-CHLOROETHYLVINYL ETHER	10 U		200 U		1000 U		10 U
BROMOFORM	5 U		100 U		500 U		5 U
2-HEXANONE	10 U		200 U		1000 U		10 U
4-METHYL-2-PENTANONE	10 U		200 U		1000 U		10 U
TETRACHLOROETHENE	5 U		100 U		500 U		5 U
1,1,2,2-TETRACHLOROETHANE	5 U		100 U		500 U		5 U
TOLUENE	5 U		33 J		740		5 U
CHLOROBENZENE	5 U		100 U		500 U		5 U
ETHYLBENZENE	5 U		85 J		500 U		5 U
STYRENE	5 U		100 U		500 U		5 U
TOTAL XYLENES	5 U		85 J		500 J		5 U
PESTICIDES/PCB (ug/l)	V	NA	V	NA	V	NA	V
ALPHA-BHC	0.05 U		0.05 U		0.05 U		0.05 U
BETA-BHC	0.05 U		0.05 U		0.05 U		0.05 U
DELTA-BHC	0.05 U		0.05 U		0.05 U		0.05 U
GAMMA-BHC (LINDANE)	0.05 U		0.05 U		0.05 U		0.05 U
HEPTACHLOR	0.05 U		0.05 U		0.05 U		0.05 U
ALDRIN	0.05 U		0.05 U		0.05 U		0.05 U
HEPTACHLOR EPOXIDE	0.05 U		0.05 U		0.05 U		0.05 U
ENDOSULFAN I	0.05 U		0.05 U		0.05 U		0.05 U
DIELDRIN	0.10 U		0.10 U		0.10 U		0.10 U
4,4'-DDE	0.10 U		0.10 U		0.10 U		0.10 U
ENDRIN	0.10 U		0.10 U		0.10 U		0.10 U
ENDOSULFAN II	0.10 U		0.10 U		0.10 U		0.10 U
4,4'-DDD	0.10 U		0.10 U		0.10 U		0.10 U
ENDRIN ALDEHYDE	0.10 U		0.10 U		0.10 U		0.10 U
ENDOSULFAN SULFATE	0.10 U		0.10 U		0.10 U		0.10 U
4,4'-DDT	0.10 U		0.10 U		0.10 U		0.10 U
METHOXYCHLOR	0.50 U		0.50 U		0.50 U		0.50 U
ENDRIN KETONE	0.10 U		0.10 U		0.10 U		0.10 U
CHLORDANE	0.50 U		0.50 U		0.50 U		0.50 U
TOXAPHENE	1.0 U		1.0 U		1.0 U		1.0 U
AROCLOR-1016	0.50 U		0.50 U		0.50 U		0.50 U
AROCLOR-1221	0.50 U		0.50 U		0.50 U		0.50 U
AROCLOR-1232	0.50 U		0.50 U		0.50 U		0.50 U
AROCLOR-1242	0.50 U		0.50 U		0.50 U		0.50 U
AROCLOR-1248	0.50 U		0.50 U		0.50 U		0.50 U
AROCLOR-1254	1.0 U		1.0 U		1.0 U		1.0 U
AROCLOR-1260	1.0 U		1.0 U		1.0 U		1.0 U
INORGANICS (ug/l)	Q	V	Q	V	V	V	Q
SILVER	10 U	NA	10 U	NA	10 U	NA	10 U
ARSENIC	10 U	10 U	30	26	29	10 U	14
BERYLLIUM	3 U	NA	3 U	NA	3 U	NA	3 U
CADMIUM	5 U	NA	5 U	NA	5 U	NA	5 U
CYANIDE	100 U	NA	100 U	NA	100 U	NA	100 U
CHROMIUM	13	9 U	9 U	9 U	21	24	9 U
COPPER	10 U	NA	10 U	NA	11	NA	10 U
IRON	4440	NA	7380	NA	20100	NA	6850
MERCURY	0.2 U	NA	0.2 U	NA	0.2 U	NA	0.2 U
NICKEL	30	24 U	64	24 U	29 U	44	57
NITRATE	NA	NA	100 U	NA	100 U	NA	NA
LEAD	15	5 U	5 U	5 U	18	8	5 U
ANTIMONY	44 U	NA	44 U	NA	44 U	NA	44 U
SELENIUM	5 U	NA	5 U	NA	5 U	NA	5 U
THALLIUM	10 U	NA	10 U	NA	10 U	NA	10 U
ZINC	14	17 U	33	17 U	63	41	53

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CHVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	P04-002	P05-001	P05-002	OW01-001	OW01-002	OW02-001	OW02-002
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	NA	V	NA	V	NA	V	V
CHLOROMETHANE		100 U		10 U		1000 U	10 U
BROMOMETHANE		100 U		10 U		1000 U	10 U
VINYL CHLORIDE		100 U		10 U		1000 U	10 U
CHLOROETHANE		100 U		10 U		1000 U	10 U
METHYLENE CHLORIDE		50 U		5 U		500 U	5 U
ACETONE		78 J		130		1000 U	7 J
CARBON DISULFIDE		50 U		5 U		500 U	5 U
1,1-DICHLOROETHENE		50 U		5 U		500 U	5 U
1,1-DICHLOROETHANE		50 U		5 U		500 U	5 U
TRANS-1,2-DICHLOROETHENE		50 U		5 U		500 U	5 U
CHLOROFORM		50 U		5 U		500 U	5 U
1,2-DICHLOROETHANE		50 U		5 U		500 U	5 U
2-BUTANONE		100 U		18		1000 U	10 U
1,1,1-TRICHLOROETHANE		50 U		5 U		500 U	5 U
CARBON TETRACHLORIDE		50 U		5 U		500 U	5 U
VINYL ACETATE		100 U		10 U		1000 U	10 U
BROMODICHLOROMETHANE		50 U		5 U		500 U	5 U
1,2-DICHLOROPROPANE		50 U		5 U		500 U	5 U
TRANS-1,3-DICHLOROPROPENE		50 U		5 U		500 U	5 U
TRICHLOROETHENE		50 U		5 U		500 U	5 U
DIBROMOCHLOROMETHANE		50 U		5 U		500 U	5 U
1,1,2-TRICHLOROETHANE		50 U		5 U		500 U	5 U
BENZENE		50 U		5 U		500 U	4 J
CIS-1,3-DICHLOROPROPENE		50 U		5 U		500 U	5 U
2-CHLOROETHYLVINYL ETHER		100 U		10 U		1000 U	10 U
BROMOFORM		50 U		5 U		500 U	5 U
2-HEXANONE		100 U		10 U		1000 U	10 U
4-METHYL-2-PENTANONE		100 U		10 U		1000 U	10 U
TETRACHLOROETHENE		50 U		5 U		500 U	5 U
1,1,2,2-TETRACHLOROETHANE		50 U		5 U		500 U	5 U
TOLUENE		50 U		5 U		500 U	16
CHLOROBENZENE		50 U		5 U		500 U	5 U
ETHYLBENZENE		50 U		5 U		500 U	7
STYRENE		50 U		5 U		500 U	5 U
TOTAL XYLENES		50 U		5 J		500 U	19
PESTICIDES/PCB (ug/l)	NA	V	NA	V	V	V	NA
ALPHA-BHC		0.05 U		0.50 U	0.25 U	0.05 U	
BETA-BHC		0.05 U		110	0.57	0.05 U	
DELTA-BHC		0.05 U		0.50 U	0.25 U	0.05 U	
GAMMA-BHC (LINDANE)		0.05 U		0.50 U	0.25 U	0.05 U	
HEPTACHLOR		0.05 U		0.50 U	0.25 U	0.05 U	
ALDRIN		0.05 U		0.50 U	0.25 U	0.05 U	
HEPTACHLOR EPOXIDE		0.05 U		0.50 U	0.25 U	0.05 U	
ENDOSULFAN I		0.05 U		0.50 U	0.25 U	0.05 U	
DIELDRIN		0.10 U		1.00 U	0.50 U	0.10 U	
4,4'-DDE		0.10 U		1.00 U	0.50 U	0.10 U	
ENDRIN		0.10 U		1.00 U	0.50 U	0.10 U	
ENDOSULFAN II		0.10 U		1.00 U	0.50 U	0.10 U	
4,4'-DDD		0.10 U		1.00 U	0.50 U	0.10 U	
ENDRIN ALDEHYDE		0.10 U		1.00 U	0.50 U	0.10 U	
ENDOSULFAN SULFATE		0.10 U		1.00 U	0.50 U	0.10 U	
4,4'-DDT		0.10 U		1.00 U	0.50 U	0.10 U	
METHOXYCHLOR		0.50 U		5.00 U	2.50 U	0.50 U	
ENDRIN KETONE		0.10 U		1.00 U	0.50 U	0.10 U	
CHLORDANE		0.50 U		5.00 U	2.50 U	0.50 U	
TOXAPHENE		1.0 U		10.0 U	5.0 U	1.0 U	
AROCLOR-1016		0.50 U		5.00 U	2.50 U	0.50 U	
AROCLOR-1221		0.50 U		5.00 U	2.50 U	0.50 U	
AROCLOR-1232		0.50 U		5.00 U	2.50 U	0.50 U	
AROCLOR-1242		0.50 U		5.00 U	2.50 U	0.50 U	
AROCLOR-1248		0.50 U		5.00 U	2.50 U	0.50 U	
AROCLOR-1254		1.0 U		10.0 U	5.0 U	1.0 U	
AROCLOR-1260		1.0 U		10.0 U	5.0 U	1.0 U	
INORGANICS (ug/l)	V	V	V	V	V	V	V
SILVER	NA	10 U(Q)	NA	10 U(Q)	NA	10 U	NA
ARSENIC	10 U	10 U	10 U	166	156	69	69
BERYLLIUM	NA	3 U	NA	3 U	NA	3 U	NA
CADMIUM	NA	5 U(Q)	NA	5 U(Q)	NA	5 U	NA
CYANIDE	NA	100 U	NA	100 U	NA	100 U	NA
CHROMIUM	24	25	9 U	9 U	14	9 U	9 U
COPPER	NA	17	NA	10 U	NA	10 U	NA
IRON	NA	14400	NA	6230	NA	4580	NA
MERCURY	NA	0.2 U	NA	0.2 U	NA	0.2 U	NA
NICKEL	51	29 U	24 U	40	24 U	29 U	37
NITRATE	NA	NA	NA	NA	NA	NA	NA
LEAD	7	21	5 U	28	25	5 U	11
ANTIMONY	NA	44 U(Q)	NA	44 U(Q)	NA	44 U	NA
SELENIUM	NA	5 U(Q)	NA	5 U(Q)	NA	5 U	NA
THALLIUM	NA	10 U	NA	10 U	NA	10 U	NA
ZINC	57	87	19	73	54	29	17 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid
(NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	OW06-001	OW06-002	OW07-001	OW07-002	OW08-001	OW08-002	OW09-001
Zone	D	D	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	V	Q	V	NA	V	NA	V
CHLOROMETHANE	10 U	10 U	10 U		10 U		10 U
BROMOMETHANE	10 U	10 U	10 U		10 U		10 U
VINYL CHLORIDE	10 U	10 U	10 U		10 U		10 U
CHLOROETHANE	10 U	10 U	10 U		10 U		10 U
METHYLENE CHLORIDE	5 U	3 J	5 U		5 U		5 U
ACETONE	51 B	10 U	10 U		10 U		10 U
CARBON DISULFIDE	5 U	5 U	5 U		5 U		5 U
1,1-DICHLOROETHENE	5 U	5 U	5 U		5 U		5 U
1,1-DICHLOROETHANE	5 U	5 U	5 U		5 U		5 U
TRANS-1,2-DICHLOROETHENE	5 U	5 U	5 U		5 U		5 U
CHLOROFORM	5 U	5 U	5 U		5 U		5 U
1,2-DICHLOROETHANE	5 U	5 U	5 U		5 U		5 U
2-BUTANONE	10 U	10 U	10 U		10 U		10 U
1,1,1-TRICHLOROETHANE	5 U	5 U	5 U		5 U		5 U
CARBON TETRACHLORIDE	5 U	5 U	5 U		5 U		5 U
VINYL ACETATE	10 U	10 U	10 U		10 U		10 U
BROMODICHLOROMETHANE	5 U	5 U	5 U		5 U		5 U
1,2-DICHLOROPROPANE	5 U	5 U	5 U		5 U		5 U
TRANS-1,3-DICHLOROPROPENE	5 U	5 U	5 U		5 U		5 U
TRICHLOROETHENE	5 U	5 U	5 U		5 U		5 U
DIBROMOCHLOROMETHANE	5 U	5 U	5 U		5 U		5 U
1,1,2-TRICHLOROETHANE	5 U	5 U	5 U		5 U		5 U
BENZENE	5 J	5 U	5 U		5 U		5 U
CIS-1,3-DICHLOROPROPENE	5 U	5 U	5 U		5 U		5 U
2-CHLOROETHYLVINYL ETHER	10 U	10 U	10 U		10 U		10 U
BROMOFORM	5 U	5 U	5 U		5 U		5 U
2-HEXANONE	10 U	10 U	10 U		10 U		10 U
4-METHYL-2-PENTANONE	10 U	10 U	10 U		10 U		10 U
TETRACHLOROETHENE	5 U	5 U	5 U		5 U		5 U
1,1,2,2-TETRACHLOROETHANE	5 U	5 U	5 U		5 U		5 U
TOLUENE	5 U	5 U	5 U		5 U		5 U
CHLOROBENZENE	5 U	5 U	5 U		5 U		5 U
ETHYLBENZENE	5 U	5 U	5 U		5 U		5 U
STYRENE	5 U	3 J	5 U		5 U		5 U
TOTAL XYLENES	5 U	5 U	5 U		5 U		5 U
PESTICIDES/PCB (ug/l)	V	Q	V	NA	V	NA	V
ALPHA-BHC	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
BETA-BHC	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
DELTA-BHC	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
GAMMA-BHC (LINDANE)	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
HEPTACHLOR	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
ALDRIN	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
HEPTACHLOR EPOXIDE	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
ENDOSULFAN I	0.05 U	0.05 U	0.05 U		0.05 U		0.05 U
DIELDRIN	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
4,4'-DDE	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
ENDRIN	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
ENDOSULFAN II	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
4,4'-DDD	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
ENDRIN ALDEHYDE	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
ENDOSULFAN SULFATE	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
4,4'-DDT	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
METHOXYCHLOR	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
ENDRIN KETONE	0.10 U	0.10 U	0.10 U		0.10 U		0.10 U
CHLORDANE	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
TOXAPHENE	1.0 U	1.0 U	1.0 U		1.0 U		1.0 U
AROCLOR-1016	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
AROCLOR-1221	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
AROCLOR-1232	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
AROCLOR-1242	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
AROCLOR-1248	0.50 U	0.50 U	0.50 U		0.50 U		0.50 U
AROCLOR-1254	1.0 U	1.0 U	1.0 U		1.0 U		1.0 U
AROCLOR-1260	1.0 U	1.0 U	1.0 U		1.0 U		1.0 U
INORGANICS (ug/l)	Q	V	Q	V	V	V	V
SILVER	10 U	8 U	10 U	NA	10 U	NA	10 U
ARSENIC	10 U	10 U	95	59	22	55	13.0
BERYLLIUM	3 U	3 U	20	NA	3 U	NA	5
CADMIUM	5 U	4 U	10	NA	9	NA	5 U
CYANIDE	100 U	NA	100 U	NA	100 U	NA	100 U
CHROMIUM	9 U	9 U	155	217	19	72	31
COPPER	10 U	14 U	85	NA	13	NA	21
IRON	35700	1430 (Q)	165000	NA	5340	NA	30400
MERCURY	0.2 U	0.2 U(Q)	0.2 U	NA	0.2 U	NA	0.2 U
NICKEL	68	42	187	241	29 U	102	29 U
NITRATE	NA	NA	NA	NA	NA	NA	NA
LEAD	23	5 U	159	148	28	52	40
ANTIMONY	44 U	48 U(Q)	44 U	NA	44 U	NA	44 U
SELENIUM	5 U	5 U	5 U	NA	5 U	NA	5 U
THALLIUM	10 U	10 U	10 U	NA	10 U	NA	10 U
ZINC	156	17 U	279	352	48	146	99

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep; (B) Detected in Blank.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	GW09-002	GW10-001	GW10-002	GW11-001	GW11-002	GW13-001	GW13-002
Zone	S	S	S	S	S	S	S
VOLATILE ORGANICS (ug/l)	NA	V	V	V	V	V	NA
CHLOROMETHANE		200 U	100 U	1000 U	100 U	10 U	
BROMOMETHANE		200 U	100 U	1000 U	100 U	10 U	
VINYL CHLORIDE		200 U	100 U	1000 U	100 U	10 U	
CHLOROETHANE		200 U	100 U	1000 U	100 U	10 U	
METHYLENE CHLORIDE		140	52	500 U	60	5 U	
ACETONE		200 U	100 U	1000 J	100 U	10 U	
CARBON DISULFIDE		100 U	50 U	500 U	50 U	5 U	
1,1-DICHLOROETHENE		100 U	50 U	500 U	50 U	5 U	
1,1-DICHLOROETHANE		100 U	50 U	500 U	50 U	5 U	
TRANS-1,2-DICHLOROETHENE		100 U	50 U	500 U	50 U	5 U	
CHLOROFORM		100 U	50 U	500 U	50 U	5 U	
1,2-DICHLOROETHANE		100 U	50 U	500 U	50 U	5 U	
2-BUTANONE		200 U	100 U	1000 U	100 U	10 U	
1,1,1-TRICHLOROETHANE		100 U	50 U	500 U	50 U	5 U	
CARBON TETRACHLORIDE		100 U	50 U	500 U	50 U	5 U	
VINYL ACETATE		200 U	100 U	1000 U	100 U	10 U	
BROMODICHLOROMETHANE		100 U	50 U	500 U	50 U	5 U	
1,2-DICHLOROPROPANE		100 U	50 U	500 U	50 U	5 U	
TRANS-1,3-DICHLOROPROPENE		100 U	50 U	500 U	50 U	5 U	
TRICHLOROETHENE		100 U	50 U	500 U	50 U	5 U	
DIBROMOCHLOROMETHANE		100 U	50 U	500 U	50 U	5 U	
1,1,2-TRICHLOROETHANE		100 U	50 U	500 U	50 U	5 U	
BENZENE		290	380	500 J	300	5 U	
CIS-1,3-DICHLOROPROPENE		100 U	50 U	500 U	50 U	5 U	
2-CHLOROETHYLVINYL ETHER		200 U	100 U	1000 U	100 U	10 U	
BROMOFORM		100 U	50 U	500 U	50 U	5 U	
2-HEXANONE		200 U	100 U	1000 U	100 U	10 U	
4-METHYL-2-PENTANONE		200 U	100 U	1000 U	100 U	10 U	
TETRACHLOROETHENE		100 U	50 U	500 U	50 U	5 U	
1,1,2,2-TETRACHLOROETHANE		100 U	50 U	500 U	50 U	5 U	
TOLUENE		620	1000	590	1000	5 U	
CHLOROBENZENE		100 U	50 U	500 U	50 U	5 U	
ETHYLBENZENE		270	470	500 J	480	5 U	
STYRENE		100 U	200	500 U	66	5 U	
TOTAL XYLENES		960	1100	500 J	850	5 U	
PESTICIDES/PCB (ug/l)	NA	V	V	V	NA	V	NA
ALPHA-BHC		0.05 U	0.05 U	0.25 U		0.05 U	
BETA-BHC		0.05 U	0.05 U	0.25 U		0.05 U	
DELTA-BHC		0.05 U	0.05 U	0.25 U		0.05 U	
GAMMA-BHC (LINDANE)		0.05 U	0.05 U	0.25 U		0.05 U	
HEPTACHLOR		0.05 U	0.05 U	0.25 U		0.05 U	
ALDRIN		0.05 U	0.05 U	0.25 U		0.05 U	
HEPTACHLOR EPOXIDE		0.05 U	0.05 U	0.25 U		0.05 U	
ENDOSULFAN I		0.05 U	0.05 U	0.25 U		0.05 U	
DIELDRIN		0.10 U	0.10 U	0.50 U		0.10 U	
4,4'-DDE		0.10 U	0.10 U	0.50 U		0.10 U	
ENDRIN		0.10 U	0.10 U	0.50 U		0.10 U	
ENDOSULFAN II		0.10 U	0.10 U	0.50 U		0.10 U	
4,4'-DDD		0.10 U	0.10 U	0.50 U		0.10 U	
ENDRIN ALDEHYDE		0.10 U	0.10 U	0.50 U		0.10 U	
ENDOSULFAN SULFATE		0.10 U	0.10 U	0.50 U		0.10 U	
4,4'-DDT		0.10 U	0.10 U	0.50 U		0.10 U	
METHOXYCHLOR		0.50 U	0.50 U	2.50 U		0.50 U	
ENDRIN KETONE		0.10 U	0.10 U	0.50 U		0.10 U	
CHLORDANE		0.50 U	0.50 U	2.50 U		0.50 U	
TOXAPHENE		1.0 U	1.0 U	5.0 U		1.0 U	
AROCLOR-1016		0.50 U	0.50 U	2.50 U		0.50 U	
AROCLOR-1221		0.50 U	0.50 U	2.50 U		0.50 U	
AROCLOR-1232		0.50 U	0.50 U	2.50 U		0.50 U	
AROCLOR-1242		0.50 U	0.50 U	2.50 U		0.50 U	
AROCLOR-1248		0.50 U	0.50 U	2.50 U		0.50 U	
AROCLOR-1254		1.0 U	1.0 U	5.0 U		1.0 U	
AROCLOR-1260		1.0 U	1.0 U	5.0 U		1.0 U	
INORGANICS (ug/l)	V	V	V	V	V	V	V
SILVER	NA	10 U	8 U	50 U	NA	10 U(Q)	NA
ARSENIC	10 U	35	15	522	10 U	10 U	10 U
BERYLLIUM	NA	3 U	9	15 U	NA	3 U	NA
CADMIUM	NA	5 U	4 U	25 U	NA	5 U(Q)	NA
CYANIDE	NA	100 U	NA	5000 U	NA	100 U	NA
CHROMIUM	17	42	151	45 U	9 U	30	33
COPPER	NA	33	76	50 U	NA	13	NA
IRON	NA	35500	130000	10500	NA	10000	NA
MERCURY	NA	0.2 U	0.2 U	0.2 U	NA	0.2 U	NA
NICKEL	42	87	157	395	32	54	60
NITRATE	NA	100 U	400	NA	NA	NA	NA
LEAD	20	257	19	28	9	46	25
ANTIMONY	NA	67	48 U	220 U	NA	44 U(Q)	NA
SELENIUM	NA	5 U	5 U	25 U	NA	5 U(Q)	NA
THALLIUM	NA	10 U	10 U	50 U	NA	10 U	NA
ZINC	36	116	303	490	28	76	56

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

SOUTH CAVALCADE SITE - GROUNDWATER ANALYTICAL RESULTS

Sample Number	OW14-001	OW14-002	DW02-001	DW02-002
Zone	S	S	D	D
VOLATILE ORGANICS (ug/l)	V	V	Q	NA
CHLOROMETHANE	10 U	10 U	10 U	
BROMOMETHANE	10 U	10 U	10 U	
VINYL CHLORIDE	10 U	10 U	10 U	
CHLOROETHANE	10 U	10 U	10 U	
METHYLENE CHLORIDE	5 U	5 U	5 U	
ACETONE	12	10 U	10 U	
CARBON DISULFIDE	5 U	5 U	5 U	
1,1-DICHLOROETHENE	5 U	5 U	5 U	
1,1-DICHLOROETHANE	5 U	5 U	5 U	
TRANS-1,2-DICHLOROETHENE	5 U	5 U	5 U	
CHLOROFORM	5 U	5 U	5 U	
1,2-DICHLOROETHANE	5 U	5 U	5 U	
2-BUTANONE	10 U	10 U	10 U	
1,1,1-TRICHLOROETHANE	5 U	5 U	5 U	
CARBON TETRACHLORIDE	5 U	5 U	5 U	
VINYL ACETATE	10 U	10 U	5 U	
BROMODICHLOROMETHANE	5 U	5 U	5 U	
1,2-DICHLOROPROPANE	5 U	5 U	5 U	
TRANS-1,3-DICHLOROPROPENE	5 U	5 U	5 U	
TRICHLOROETHENE	5 U	5 U	5 U	
DIBROMOCHLOROMETHANE	5 U	5 U	5 U	
1,1,2-TRICHLOROETHANE	5 U	5 U	5 U	
BENZENE	5 U	5 U	5 U	
CIS-1,3-DICHLOROPROPENE	5 U	5 U	5 U	
2-CHLOROETHYLVINYL ETHER	10 U	10 U	10 U	
BROMOFORM	5 U	5 U	5 U	
2-HEXANONE	10 U	10 U	10 U	
4-METHYL-2-PENTANONE	10 U	10 U	10 U	
TETRACHLOROETHENE	5 U	5 U	5 U	
1,1,2,2-TETRACHLOROETHANE	5 U	5 U	5 U	
TOLUENE	9	11	5 U	
CHLOROBENZENE	5 U	5 U	5 U	
ETHYLBENZENE	10	13	5 U	
STYRENE	5 U	5 U	5 U	
TOTAL XYLENES	37	30	5 U	
PESTICIDES/PCB (ug/l)	V	NA	V	NA
ALPHA-BHC	0.05 U		0.05 U	
BETA-BHC	0.05 U		0.05 U	
DELTA-BHC	0.05 U		0.05 U	
GAMMA-BHC (LINDANE)	0.05 U		0.05 U	
HEPTACHLOR	0.05 U		0.05 U	
ALDRIN	0.05 U		0.05 U	
HEPTACHLOR EPOXIDE	0.05 U		0.05 U	
ENDOSULFAN I	0.05 U		0.05 U	
DIELDRIN	0.10 U		0.10 U	
4,4'-DDE	0.10 U		0.10 U	
ENDRIN	0.10 U		0.10 U	
ENDOSULFAN II	0.10 U		0.10 U	
4,4'-DDD	0.10 U		0.10 U	
ENDRIN ALDEHYDE	0.10 U		0.10 U	
ENDOSULFAN SULFATE	0.10 U		0.10 U	
4,4'-DDT	0.10 U		0.10 U	
METHOXYCHLOR	0.50 U		0.50 U	
ENDRIN KETONE	0.10 U		0.10 U	
CHLORDANE	0.50 U		0.50 U	
TOXAPHENE	1.0 U		1.00 U	
AROCLOR-1016	0.50 U		0.50 U	
AROCLOR-1221	0.50 U		0.50 U	
AROCLOR-1232	0.50 U		0.50 U	
AROCLOR-1242	0.50 U		0.50 U	
AROCLOR-1248	0.50 U		0.50 U	
AROCLOR-1254	1.0 U		1.00 U	
AROCLOR-1260	1.0 U		1.00 U	
INORGANICS (ug/l)	V	V	V	V
SILVER	10 U	NA	8 U	8 U
ARSENIC	83.0	41	10 U	10 U
BERYLLIUM	6	NA	2 U	2 U
CADMIUM	5 U	NA	3 U	5 U
CYANIDE	100 U	NA	10 U	10 U
CHROMIUM	68	56	7 U	9 U
COPPER	14	NA	15 U	9 U
IRON	39500	NA	80	78 U
MERCURY	0.2 U	NA	0.2 U	0.2 U
NICKEL	29 U	66	25 U	25 U
NITRATE	NA	NA	100 U	100 U
LEAD	29	20	5 U	5 U
ANTIMONY	44 U	NA	50 U	50 U
SELENIUM	5 U	NA	5 U	5 U
THALLIUM	10 U	NA	10 U(Q)	10 U(Q)
ZINC	121	80	12 U	9 U

NOTES : (U) Undetected; (J) Present below detection limit; (NA) Not analyzed; (V) Valid; (I) Invalid (NV) Not validated; (Q) Qualified; (S) Shallow; (D) Deep.

APPENDIX B

SCENARIO 1A - WORST CASE SIMULATIONS (NORTHERN AREA)

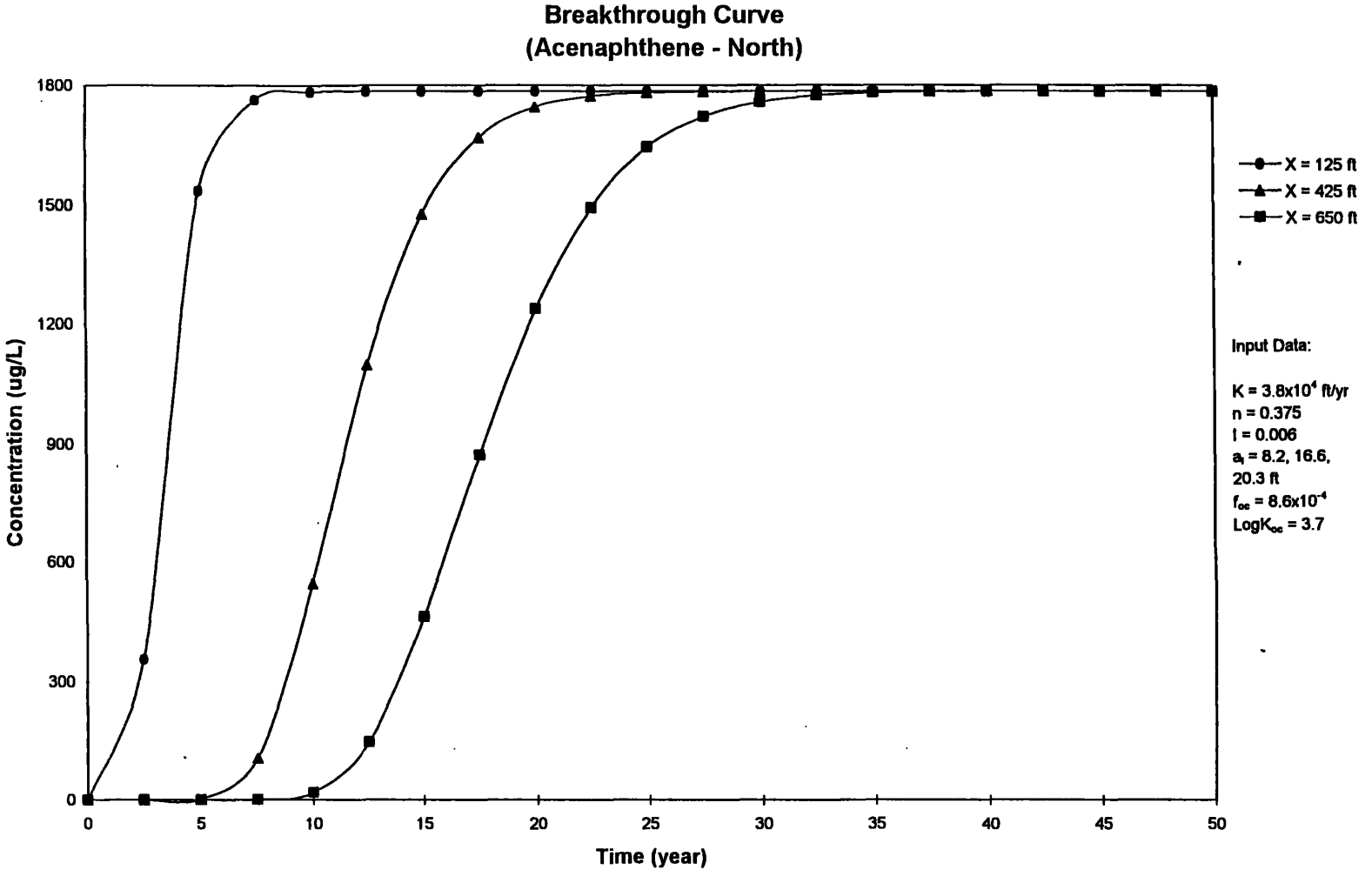
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

ACENAPHTHENE

No remedial goal for acenaphthene is specified in the ROD. The effective solubility for acenaphthene (1,790 ug/l) is slightly less than the TNRCC MSC (2,190 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 25 years.

An acenaphthene concentration of 65 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an acenaphthene concentration equal to the effective solubility of this constituent (1,790 ug/l) in monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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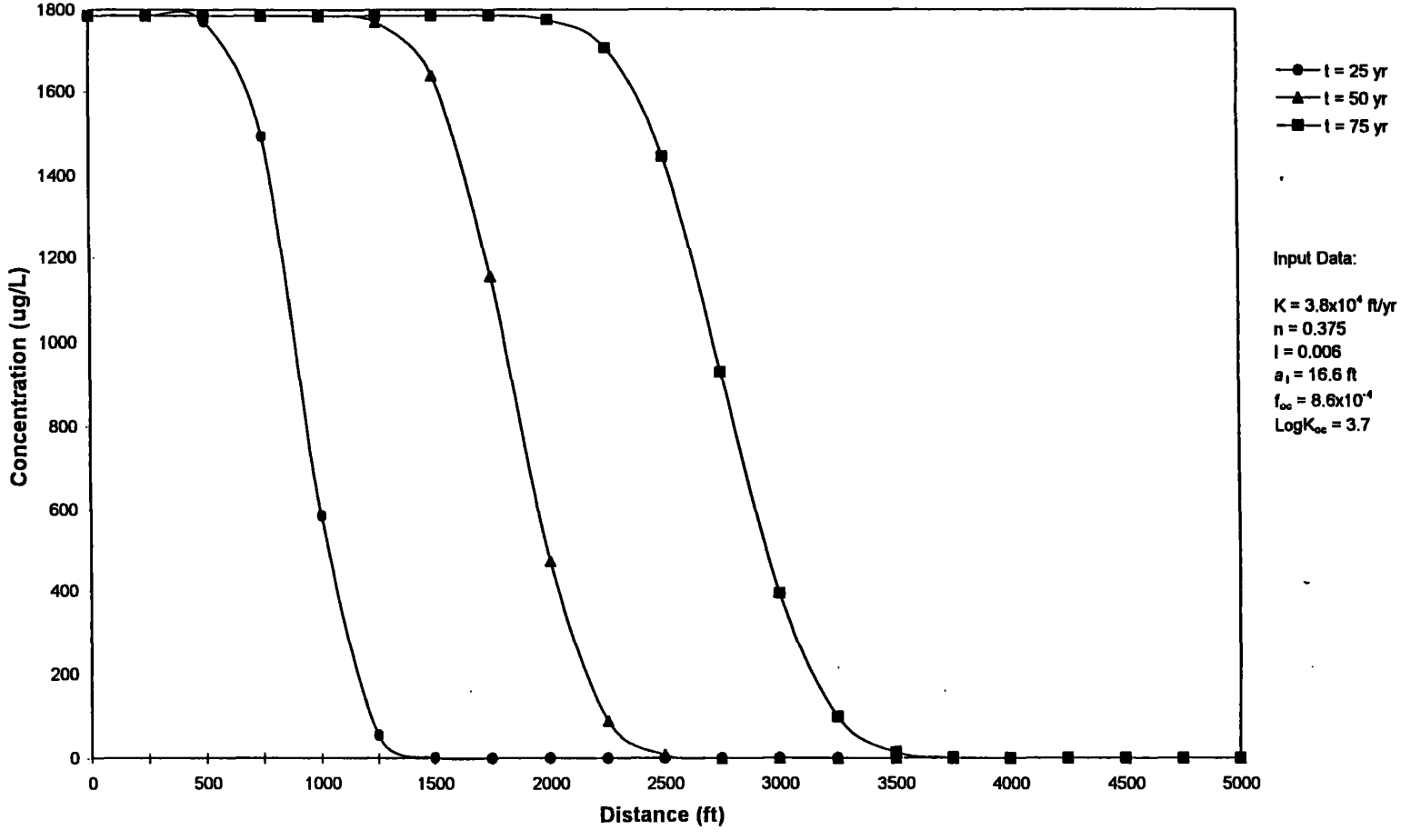
Breakthrough Curve
(Acenaphthene - North)



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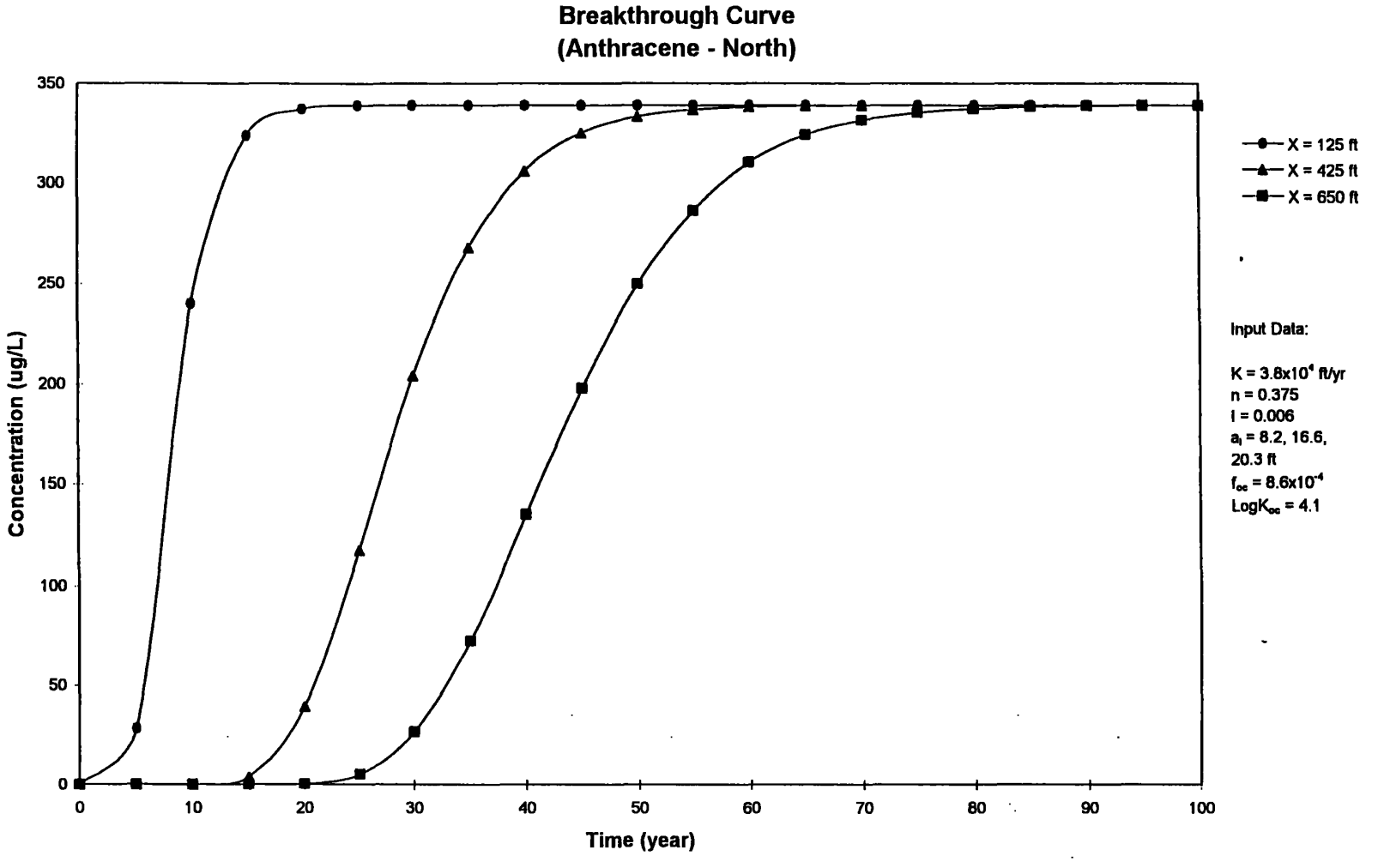
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

ANTHRACENE

No remedial goal for anthracene is specified in the ROD. The effective solubility for anthracene (339 ug/l) is much less than the TNRCC MSC (11,100 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 60 years.

An estimated anthracene concentration of 1 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an anthracene concentration of more than 300 ug/l for monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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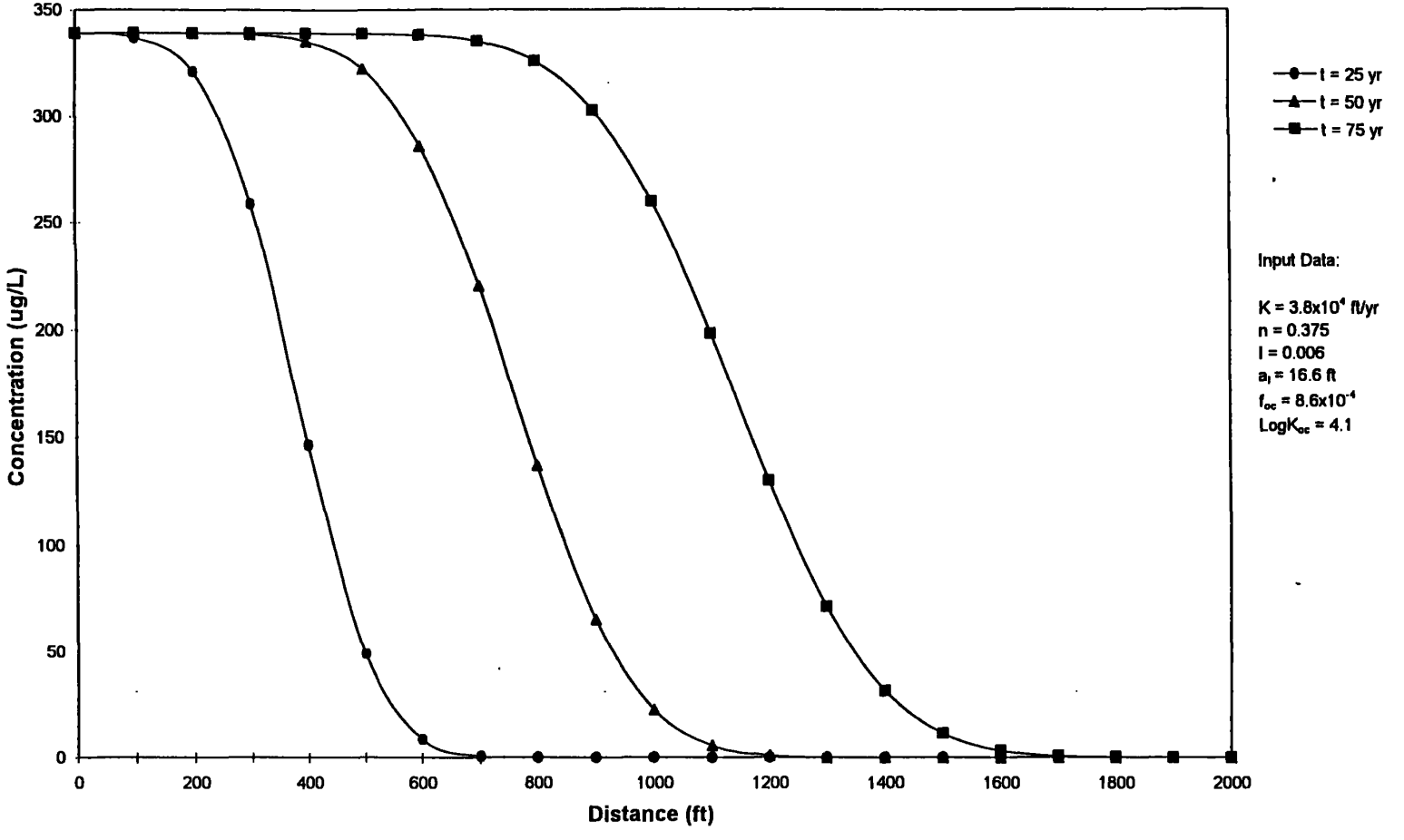
Breakthrough Curve
(Anthracene - North)



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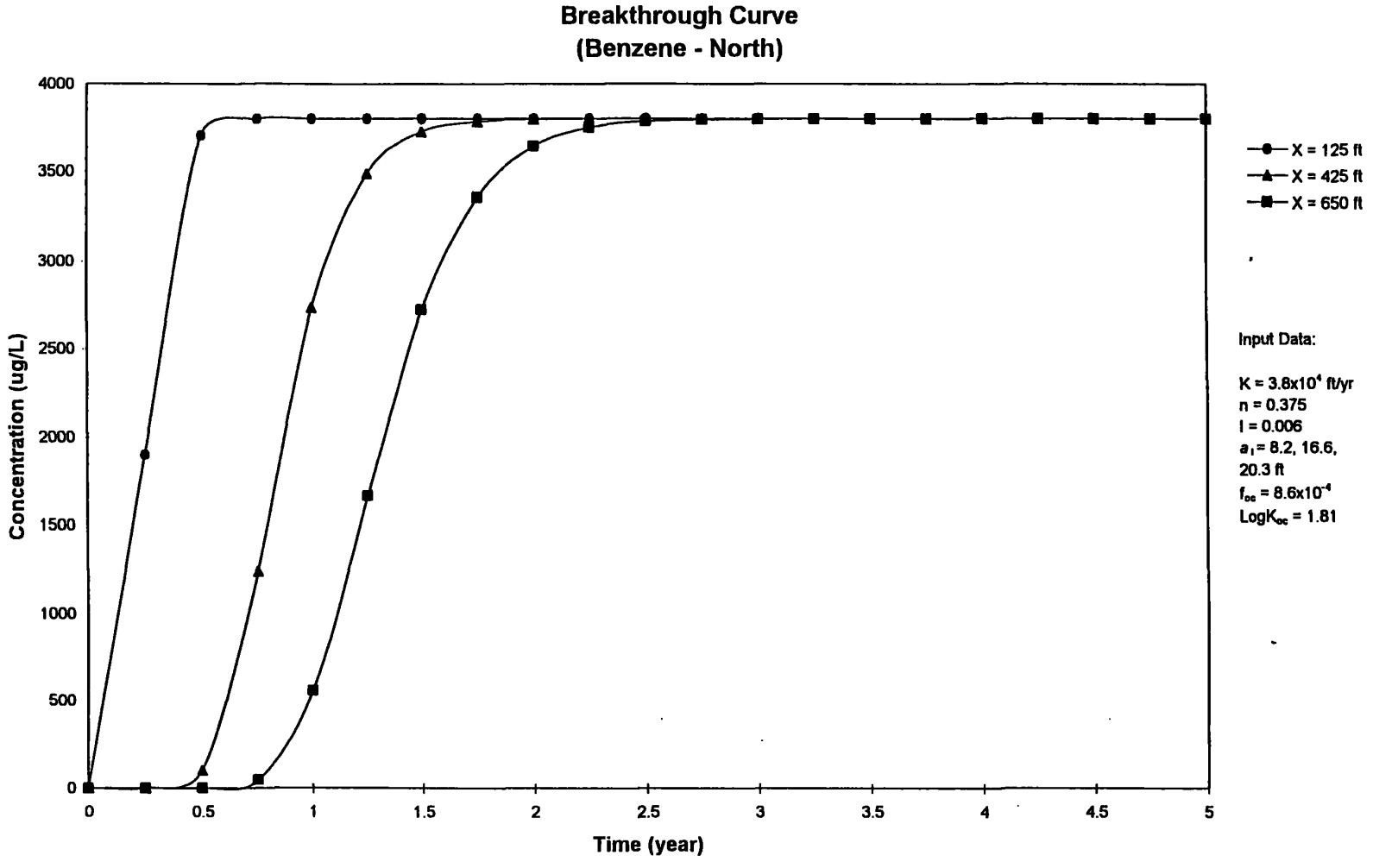
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

BENZENE

The remedial goal for benzene, as specified in the ROD, is 5 ug/l. The effective solubility for benzene is 3,799 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing benzene at a concentration equal to the ROD remedial goal to reach the hypothetical exposure endpoint (x=425 ft.) of less than 0.5 year.

An benzene concentration of 6 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts a benzene concentration equal to the effective solubility (3,800 ug/l) in monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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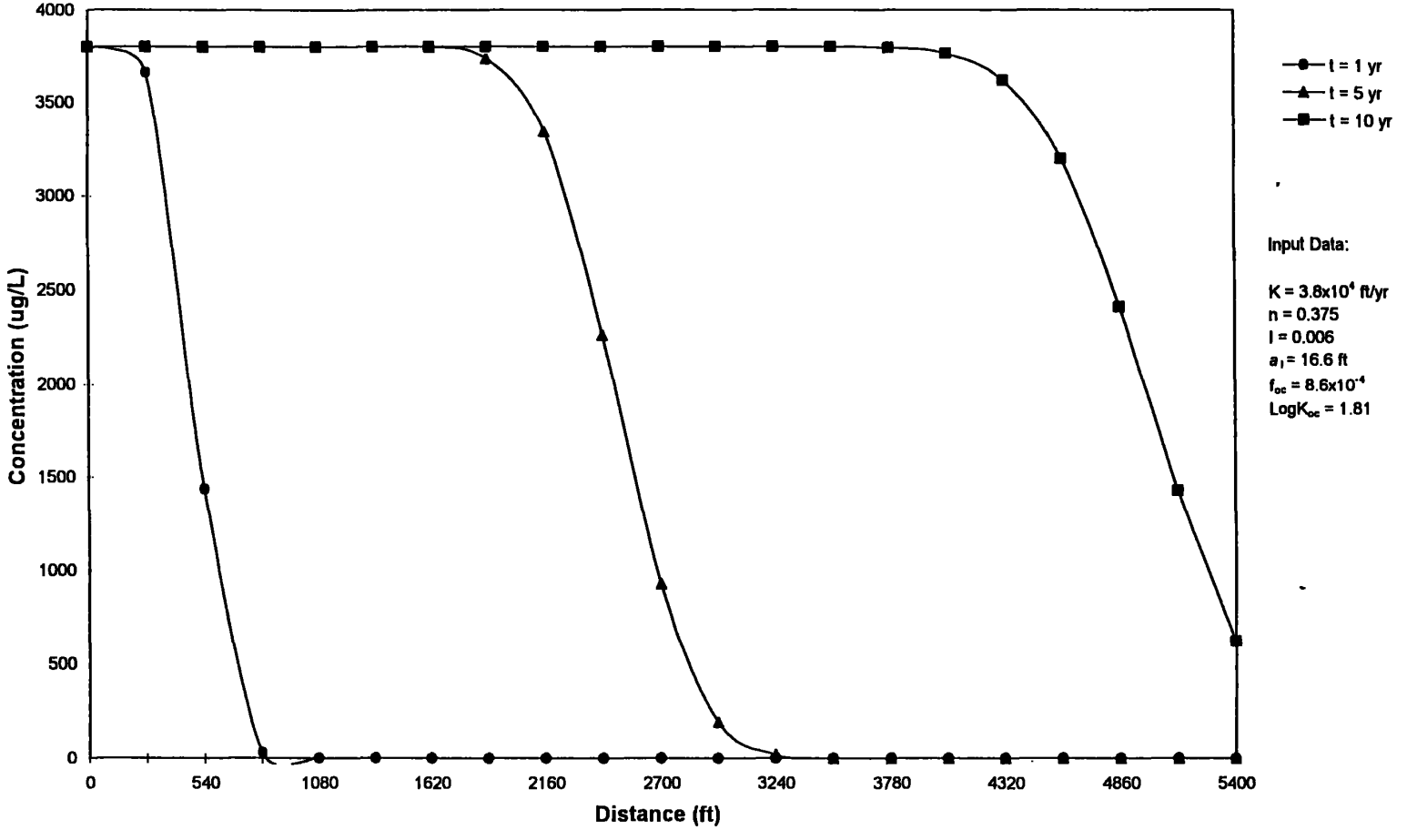
Breakthrough Curve
(Benzene - North)



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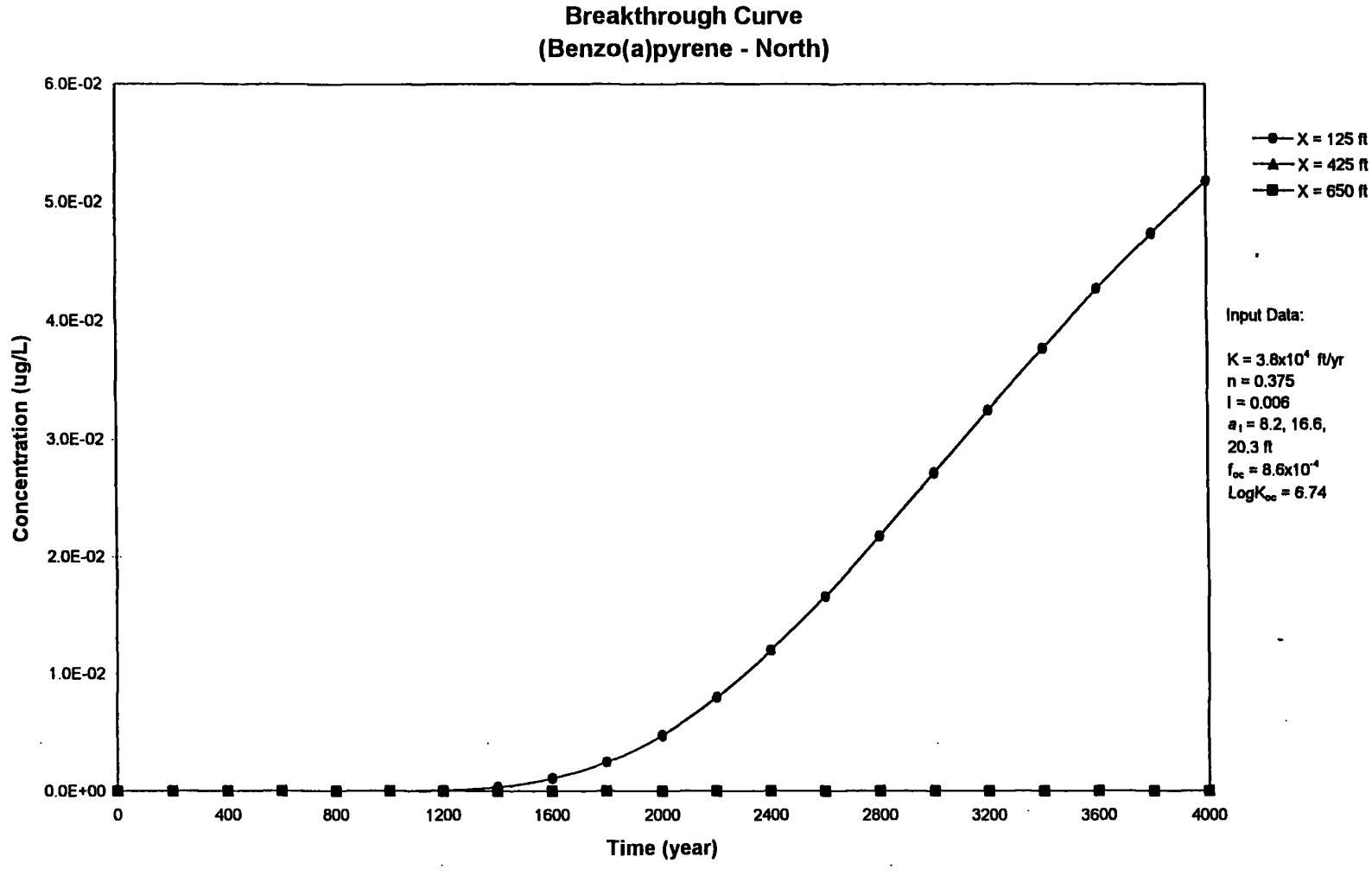
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

BENZO(a)PYRENE

Benzo(a)pyrene is considered a potentially carcinogenic PAH. The remedial goal for potentially carcinogenic PAHs as specified in the ROD is no detection. As a result, the Practical Quantitation Limit for this constituent (10 ug/l) is used as the remedial goal in this assessment. The effective solubility for benzo(a)pyrene (0.08 ug/l) is much less than the remedial goal. The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of more than 4000 years.

Benzo(a)pyrene was not detected in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Therefore, the simulated results for this constituent are consistent with the actual field data.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will not be further evaluated.



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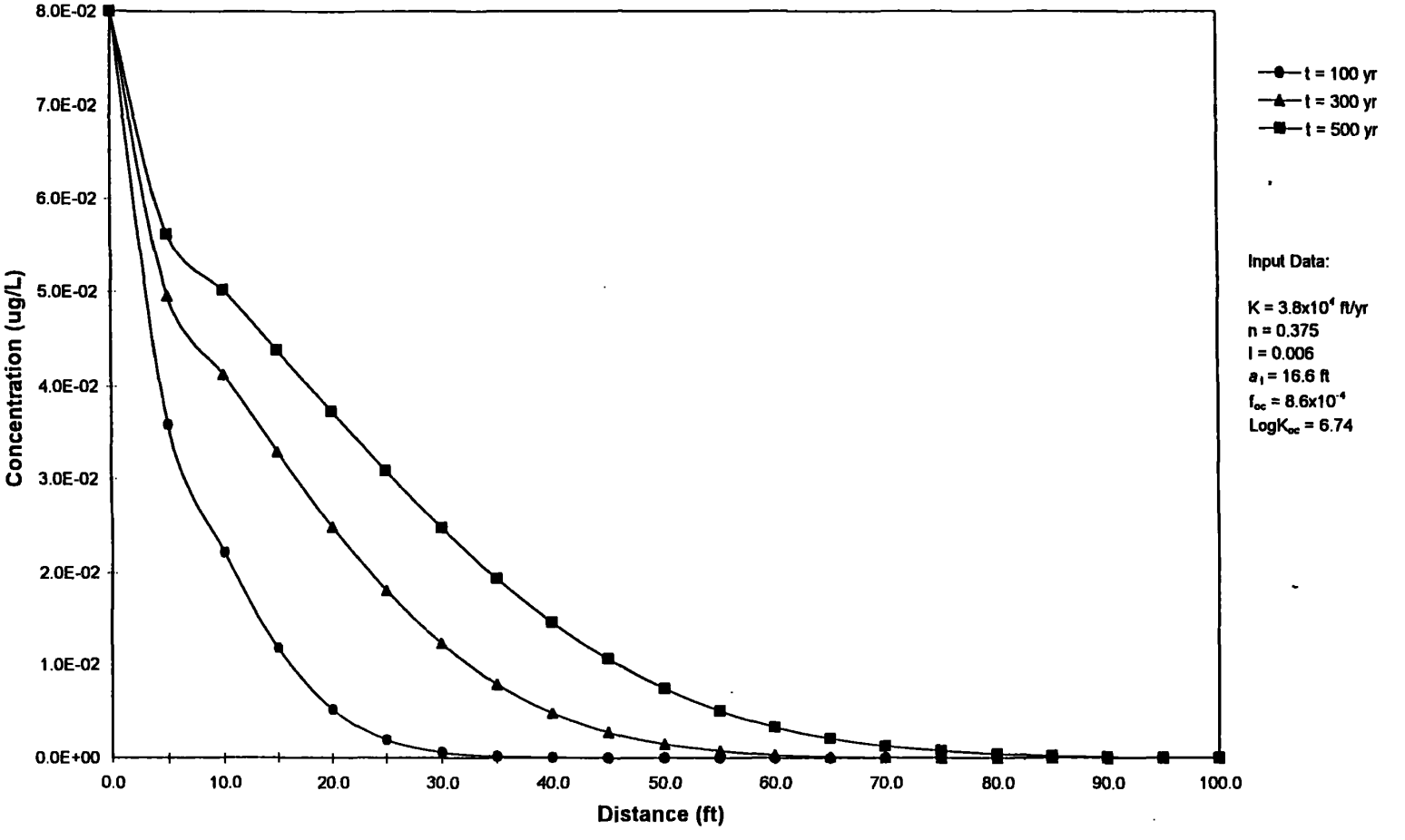
Breakthrough Curve
(Benzo(a)pyrene - North)



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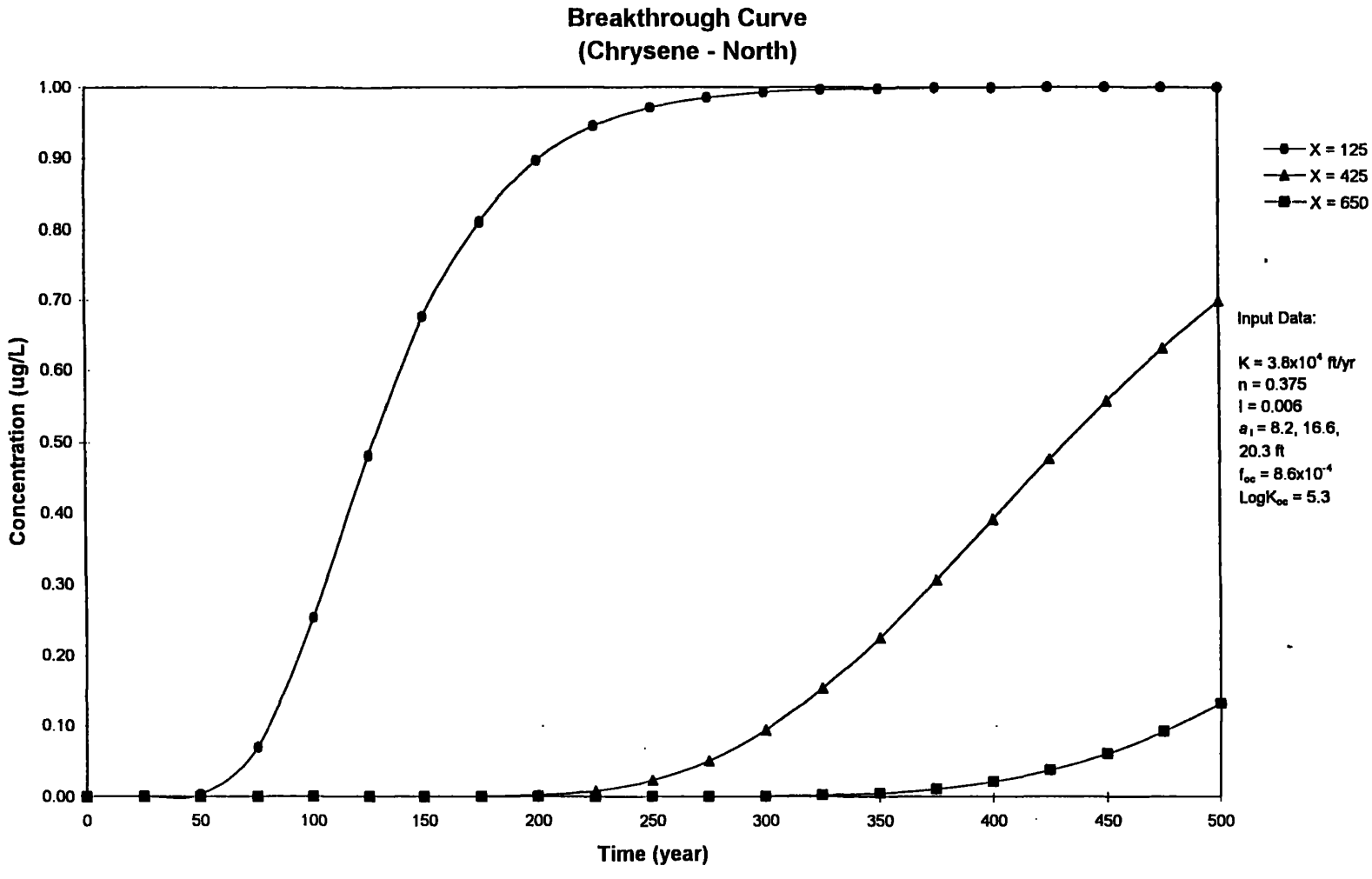
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

CHRYSENE

Chrysene is considered a potentially carcinogenic PAH. The remedial goal for potentially carcinogenic PAHs as specified in the ROD is no detection. As a result, the Practical Quantitation Limit for this constituent (10 ug/l) is used as the remedial goal in this assessment. The effective solubility for chrysene (1.0 ug/l) is less than the remedial goal. The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of more than 500 years.

Chrysene was not detected in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Therefore, the simulated results for this constituent are consistent with the actual field data.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will not be further evaluated.



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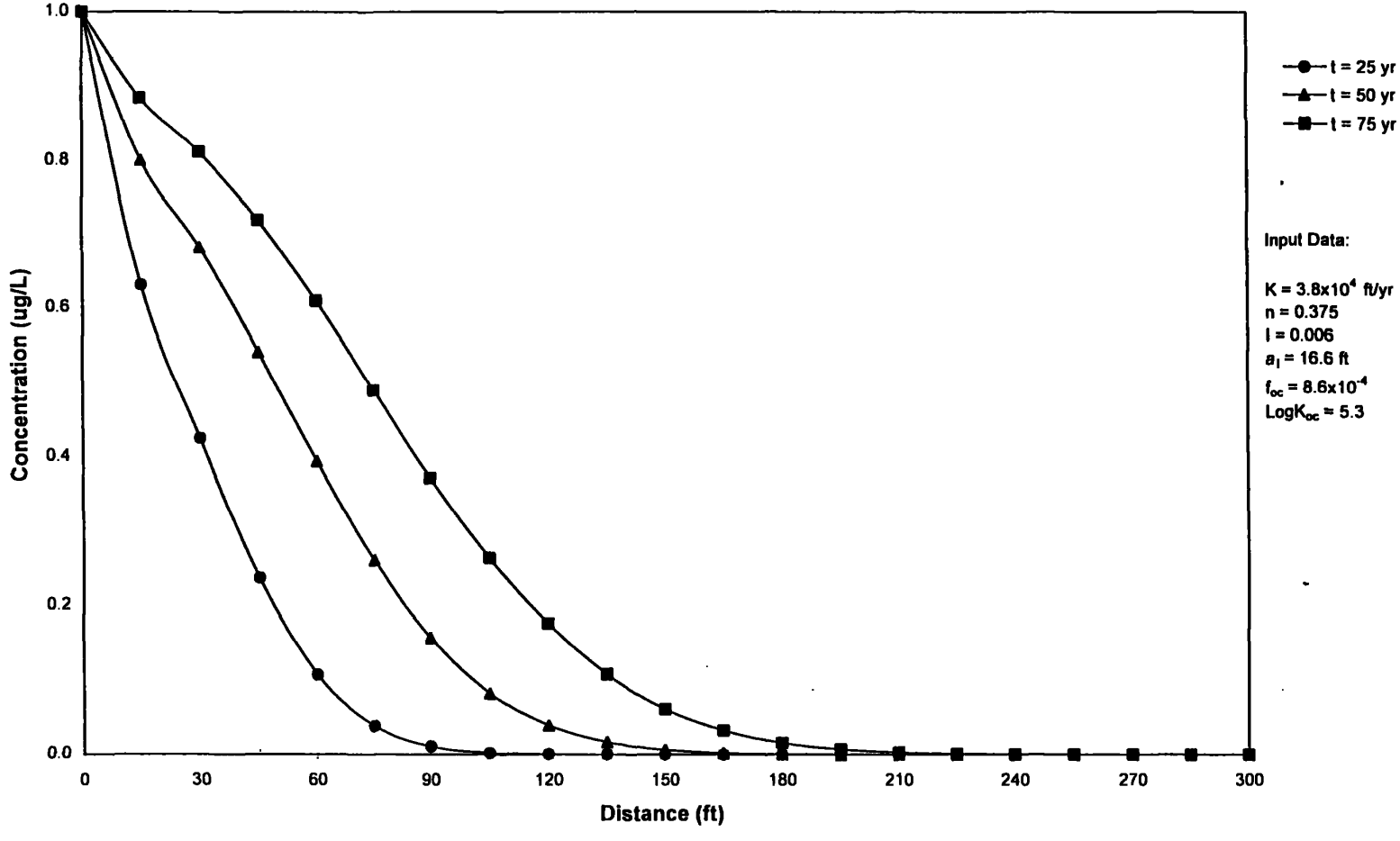
Breakthrough Curve
(Chrysene - North)



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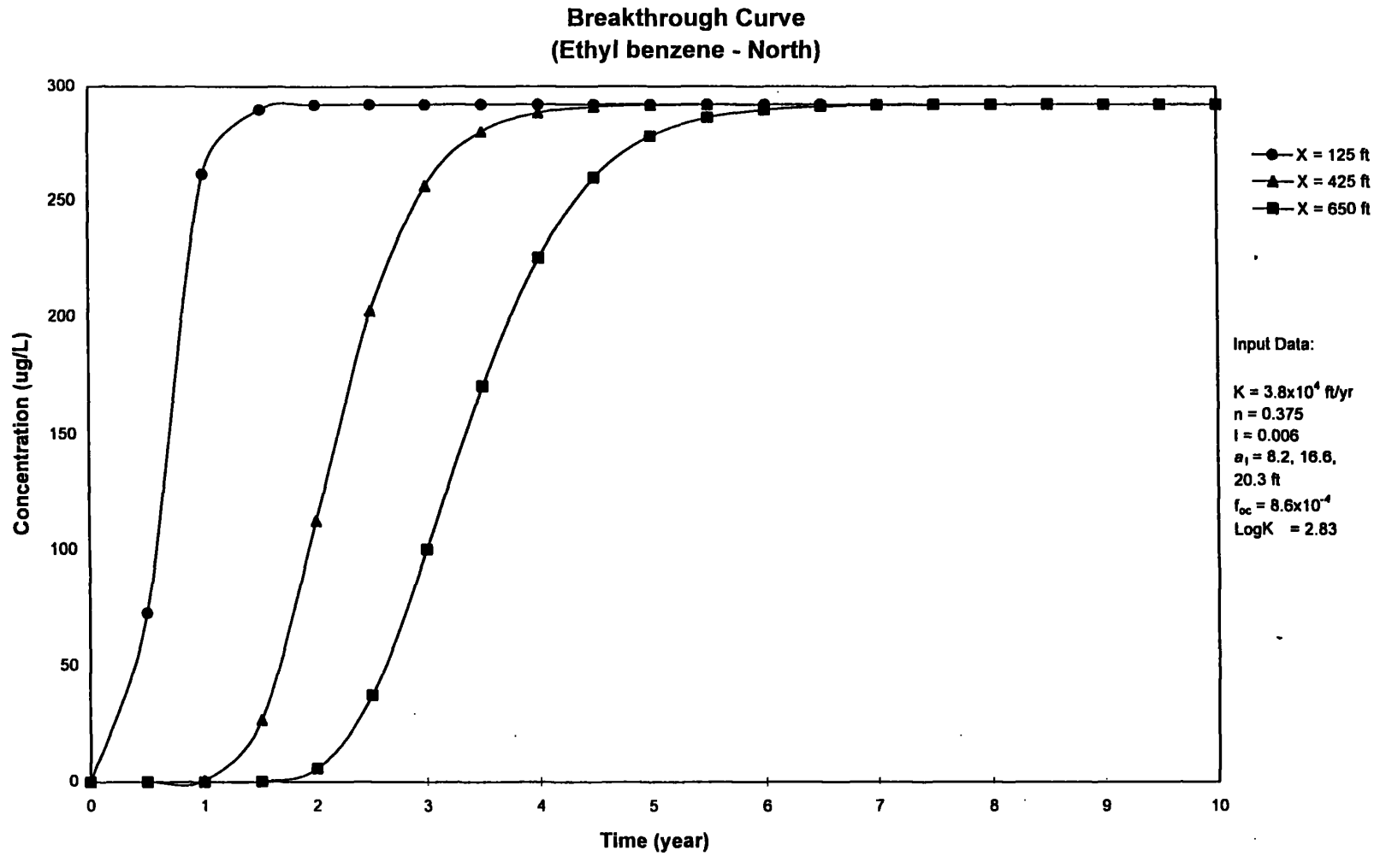
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

ETHYLBENZENE

The remedial goal for ethylbenzene, as specified in the ROD, is 142 ug/l. The effective solubility for ethylbenzene is 292 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing ethylbenzene at a concentration equal to the ROD remedial goal to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 2 years.

An ethylbenzene concentration of 8 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an ethylbenzene concentration equal to the effective solubility (292 ug/l) in monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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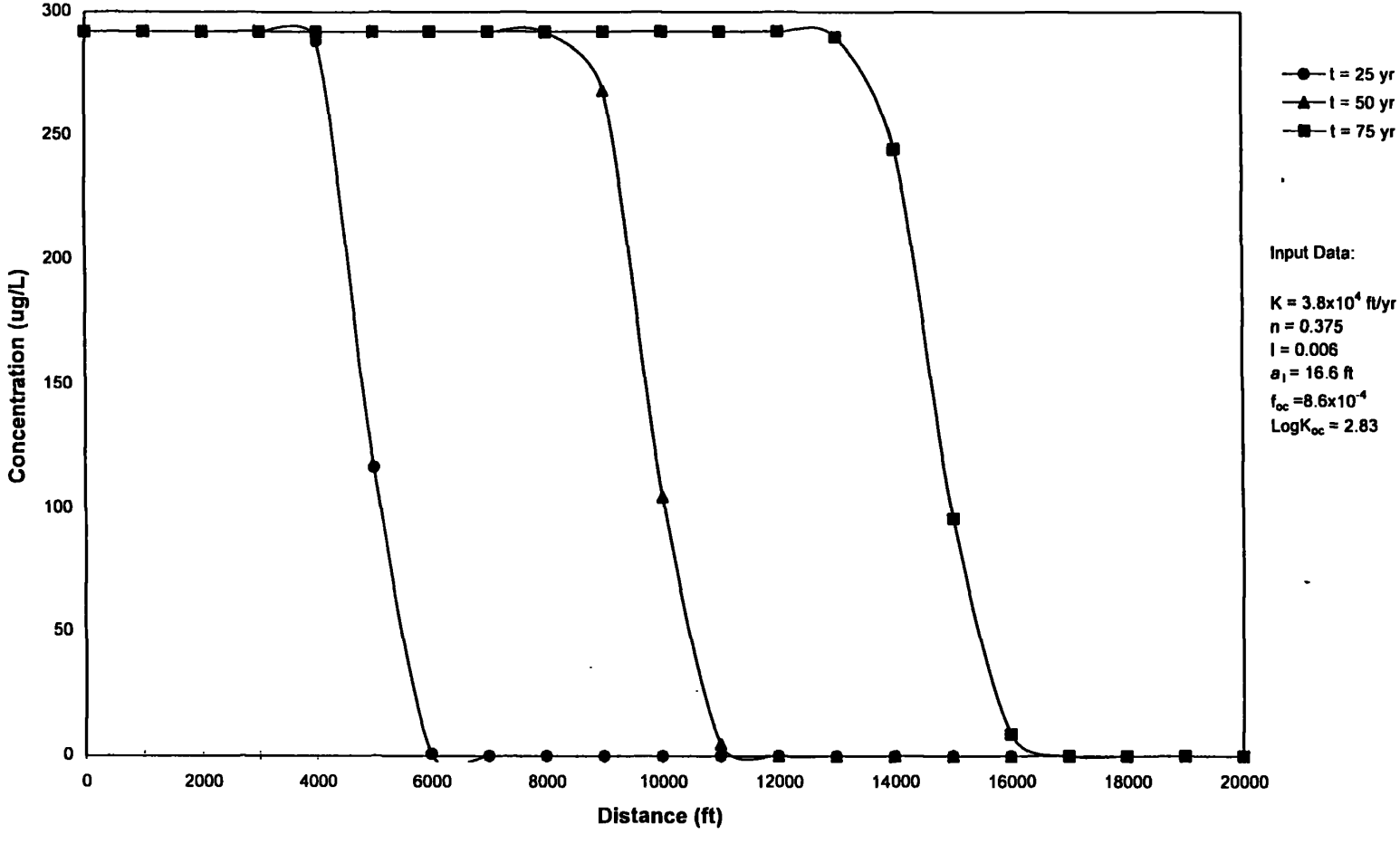
Breakthrough Curve
(Ethyl benzene - North)



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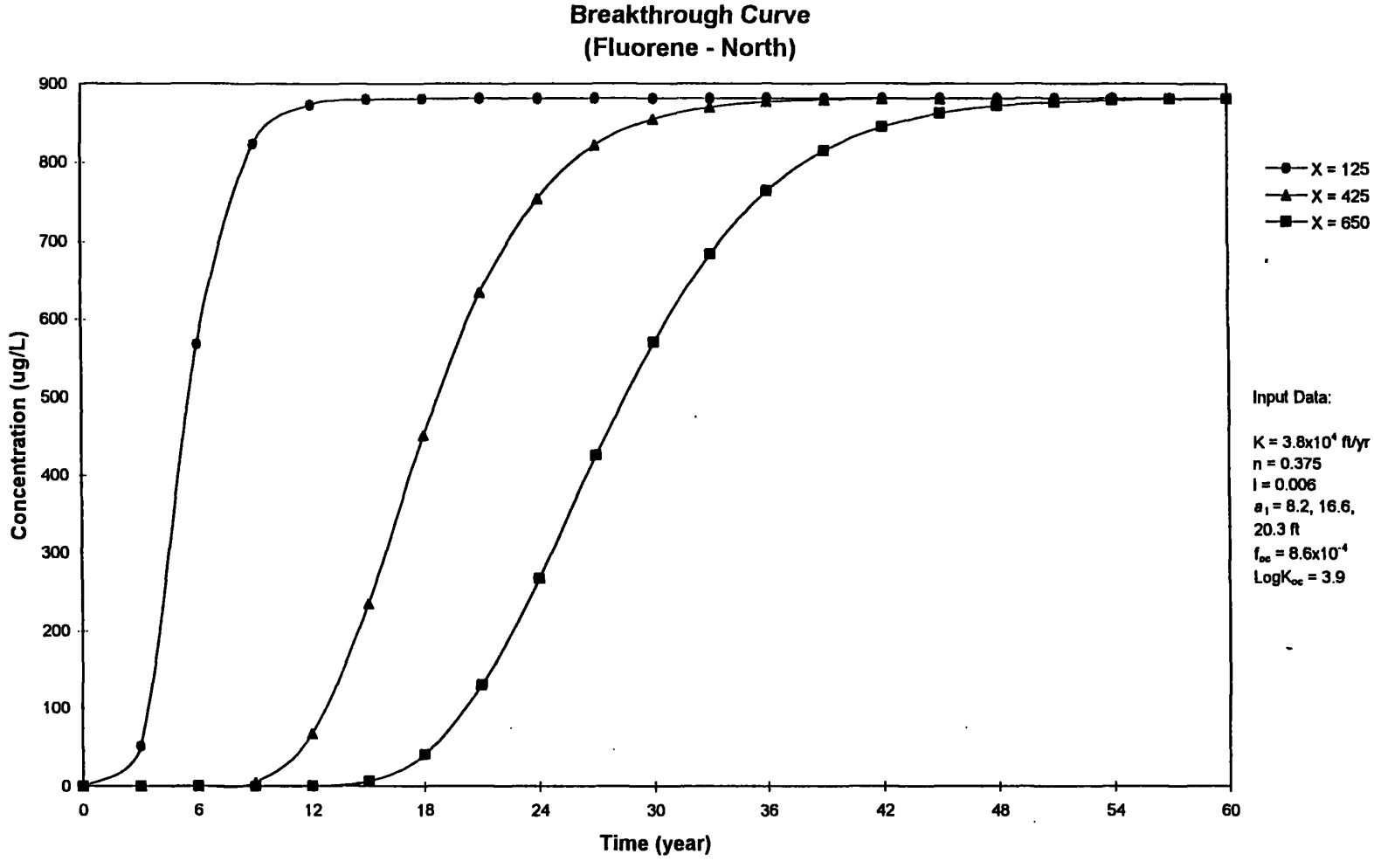
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

FLUORENE

No remedial goal for fluorene is specified in the ROD. The effective solubility for fluorene (881 ug/l) is less than the TNRCC MSC (1,460 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 36 years.

A fluorene concentration of 43 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an fluorene concentration of more than 800 ug/l for monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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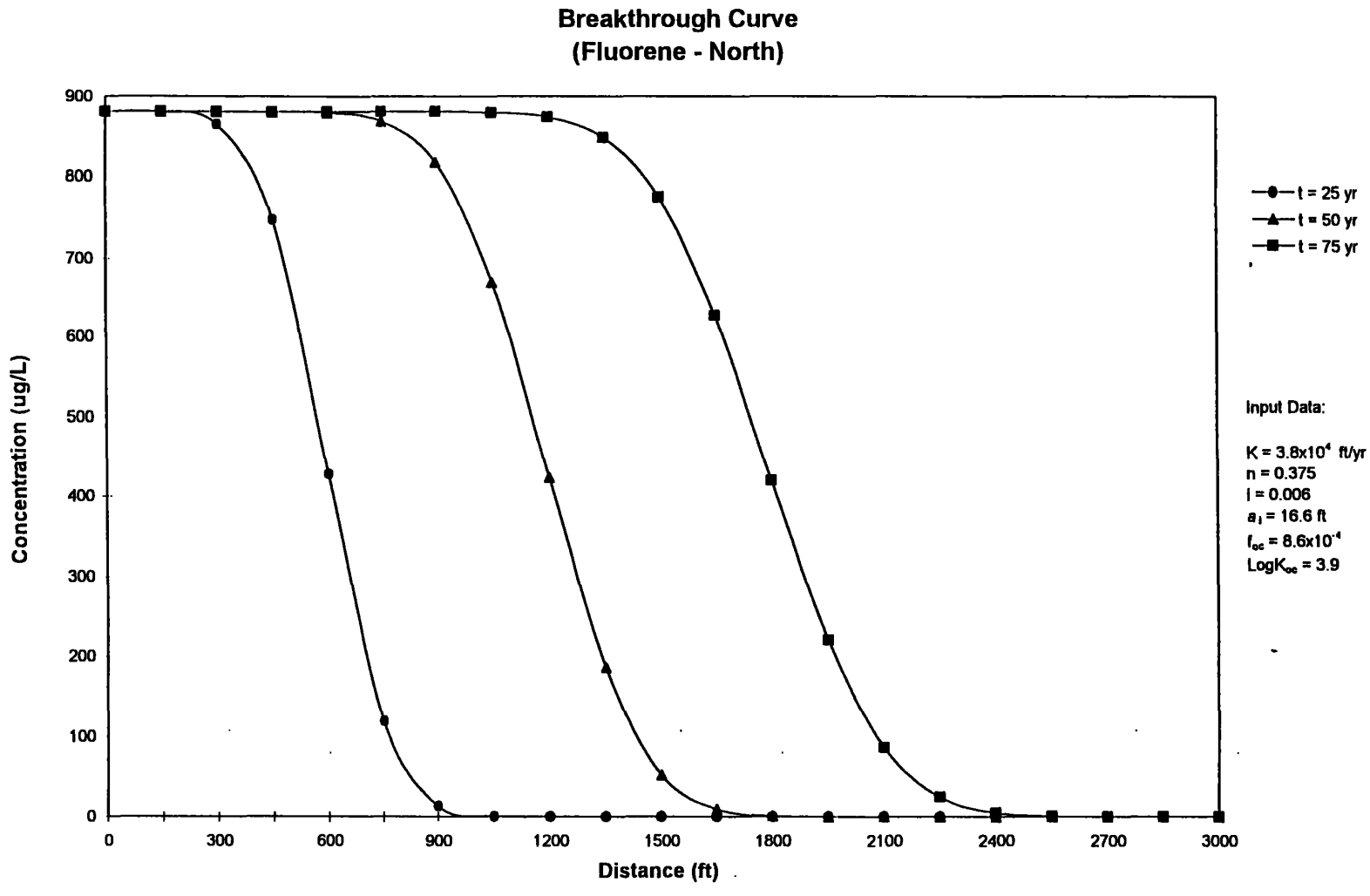

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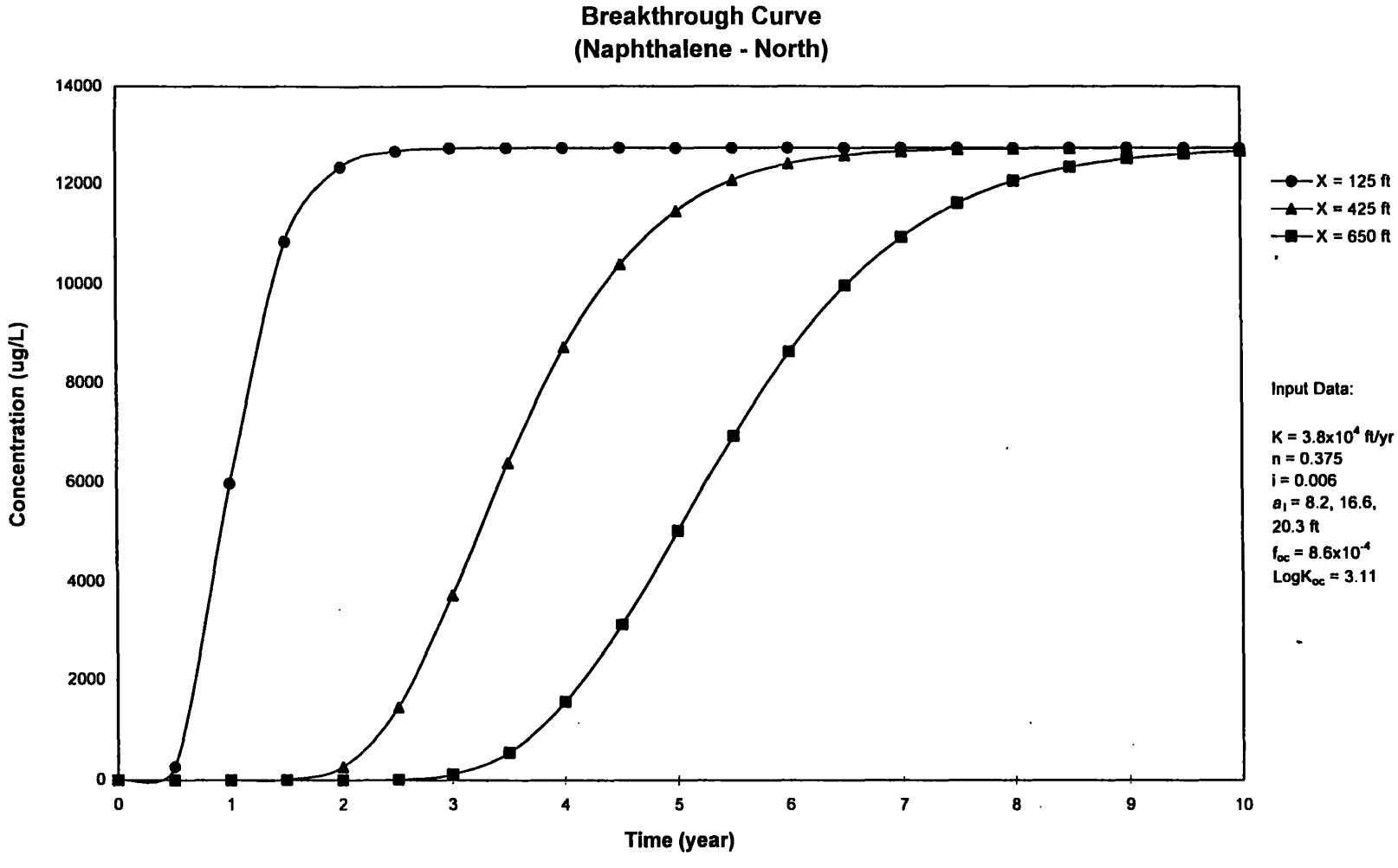
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

NAPHTHALENE

No remedial goal for naphthalene is specified in the ROD. The effective solubility for naphthalene is 12,700 ug/l and the TNRCC MSC is 1,460 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing naphthalene at a concentration equal to the TNRCC MSC to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 2.5 years.

An naphthalene concentration of 1,600 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an naphthalene concentration equal to the effective solubility (12,700 ug/l) in monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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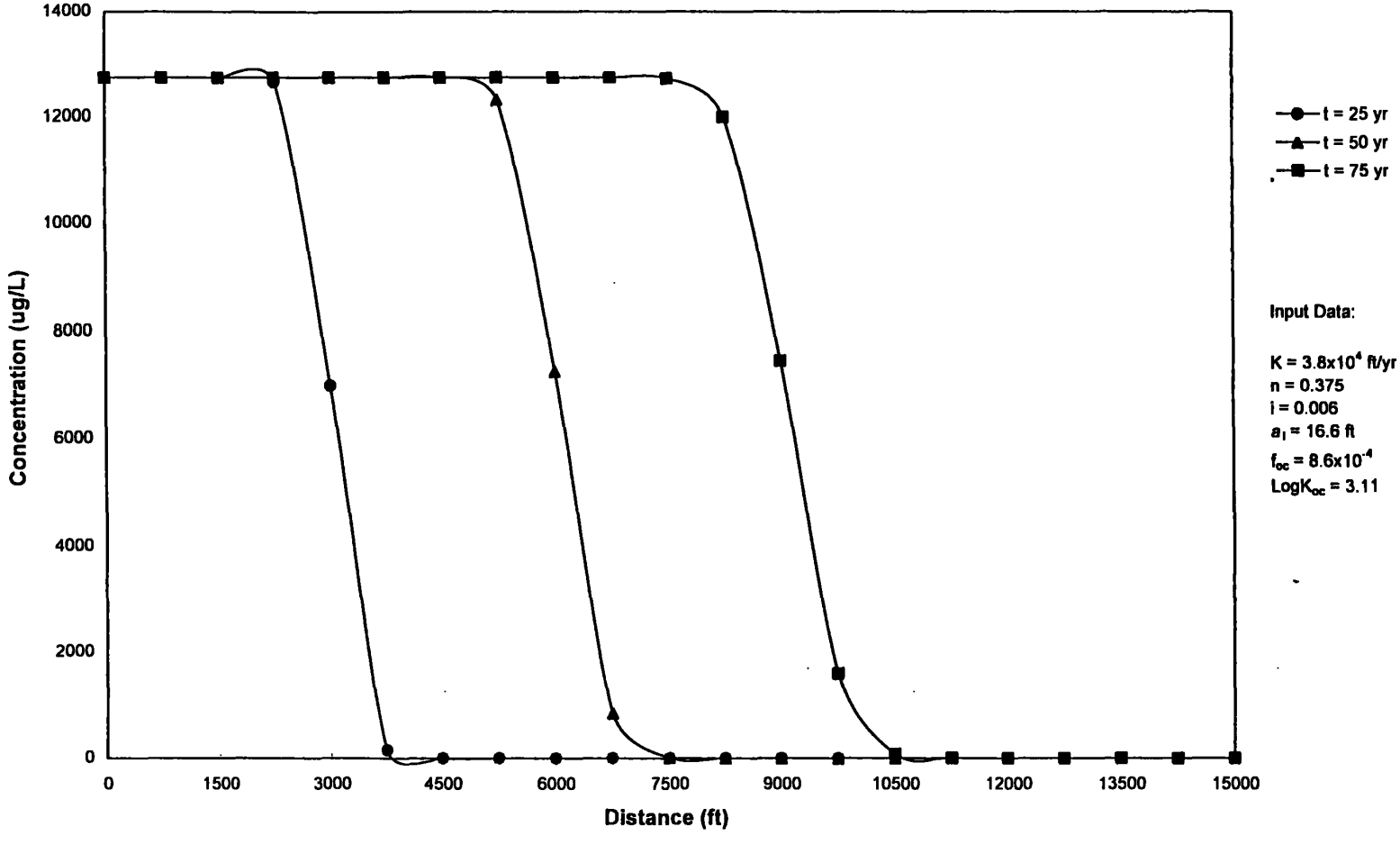
Breakthrough Curve
(Naphthalene - North)



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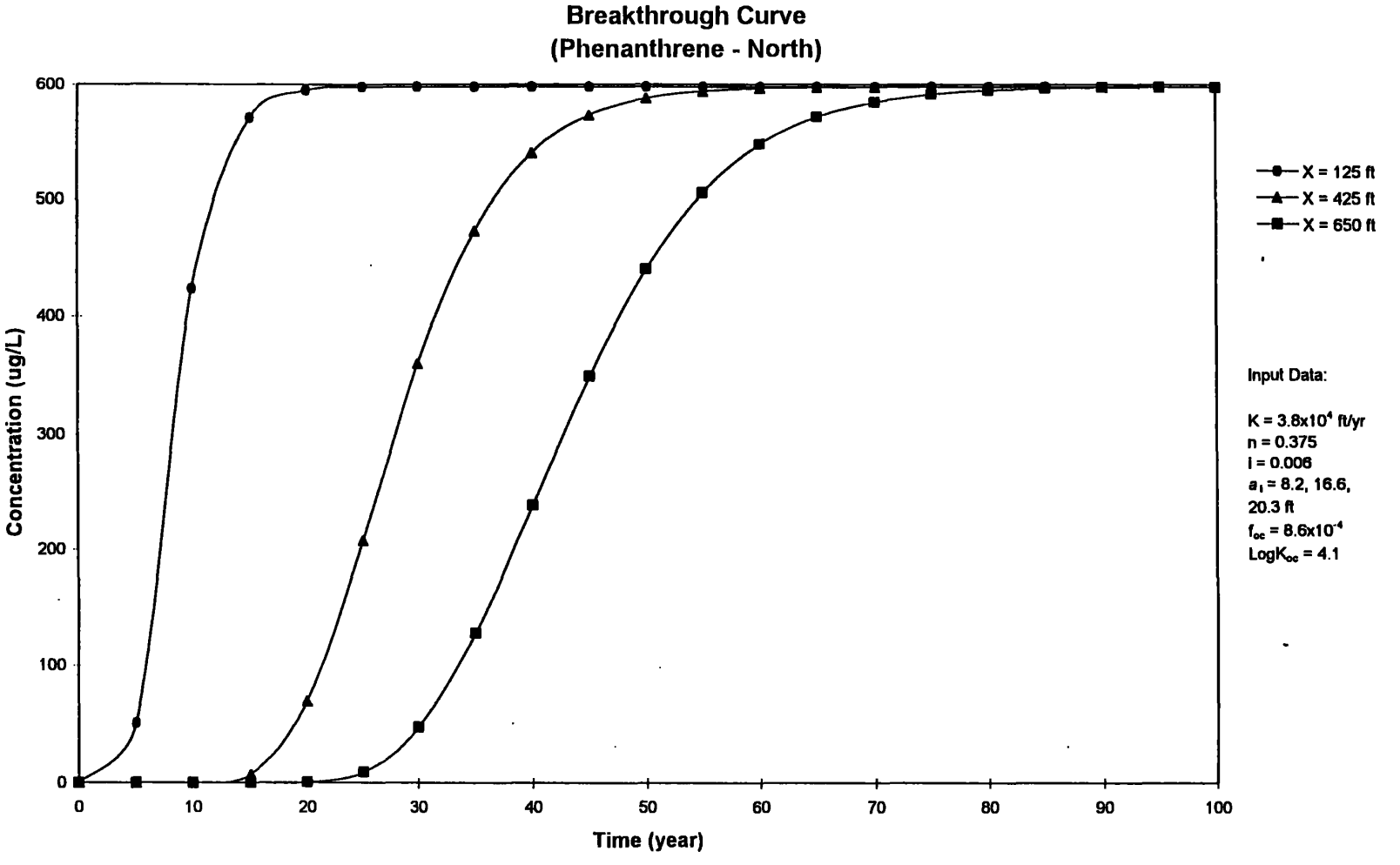
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

PHENANTHRENE

No remedial goal for phenanthrene is specified in the ROD. The effective solubility for phenanthrene (598 ug/l) is much less than the TNRCC MSC (11,100 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 60 years.

A phenanthrene concentration of 26 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an phenanthrene concentration of more than 500 ug/l for monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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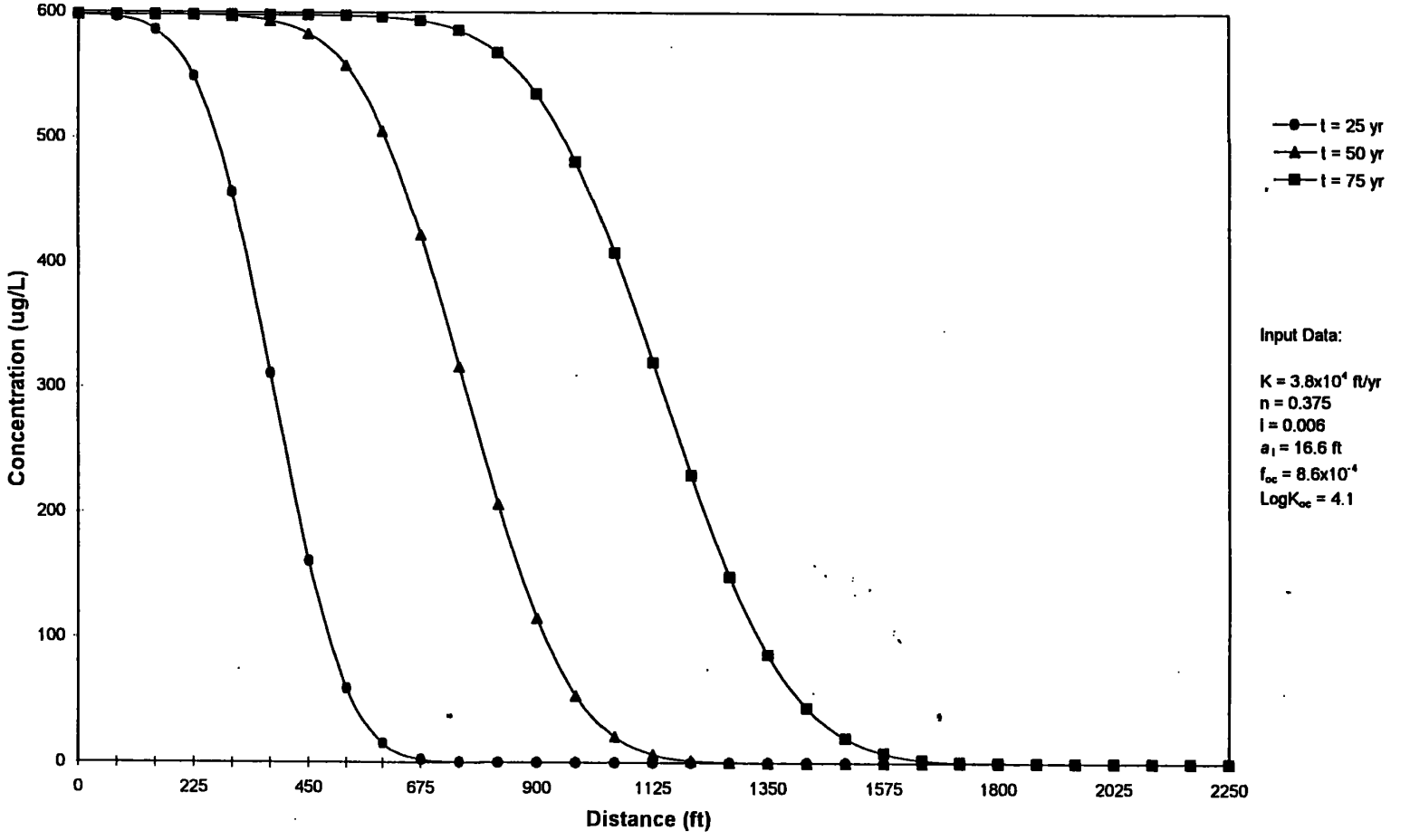
Breakthrough Curve
(Phenanthrene - North)



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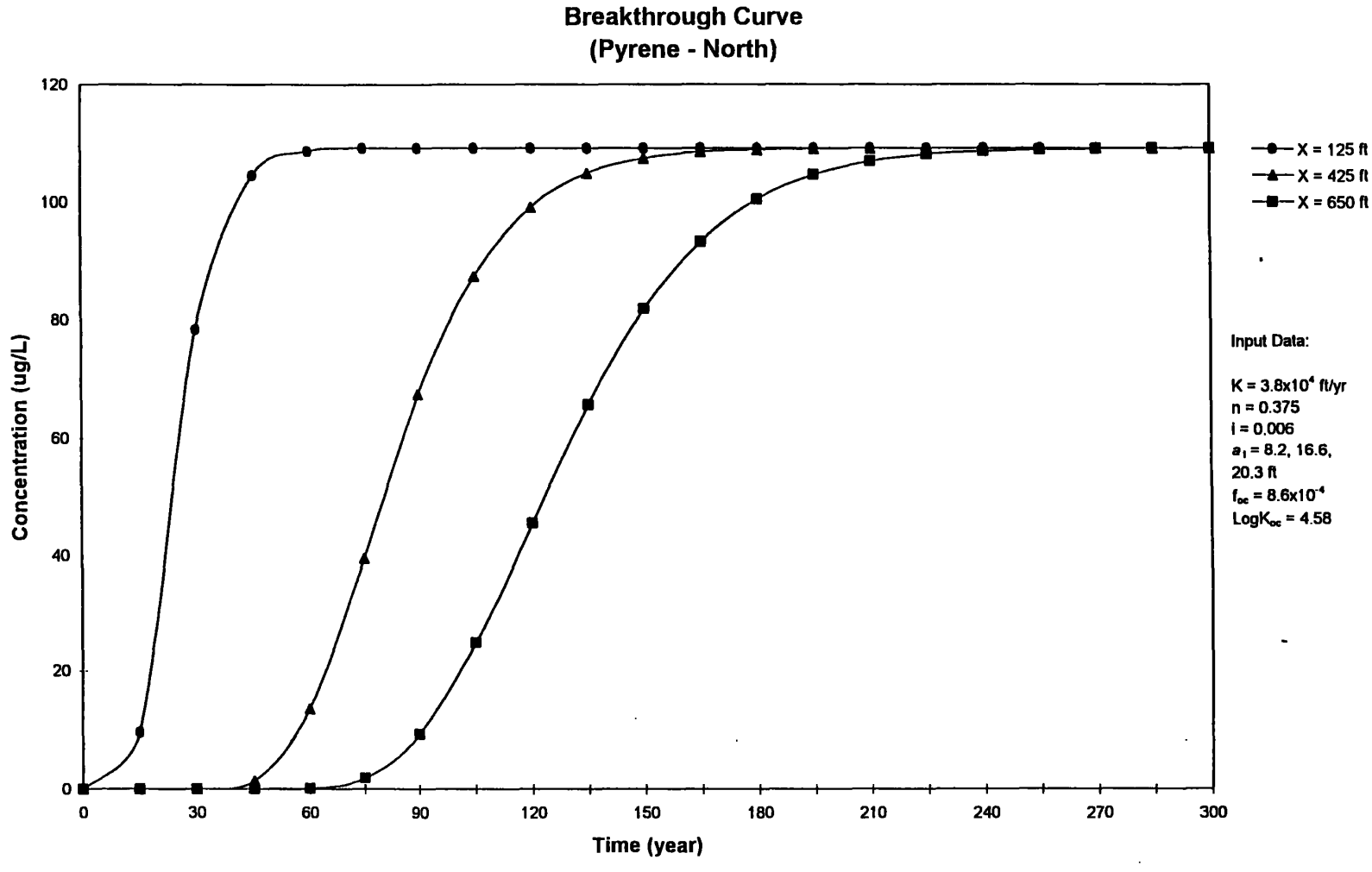
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

PYRENE

No remedial goal for pyrene is specified in the ROD. The effective solubility for pyrene (109 ug/l) is less than the TNRCC MSC (1,110 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) of approximately 165 years.

An estimated pyrene concentration of 1 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an pyrene concentration of more than 30 ug/l for monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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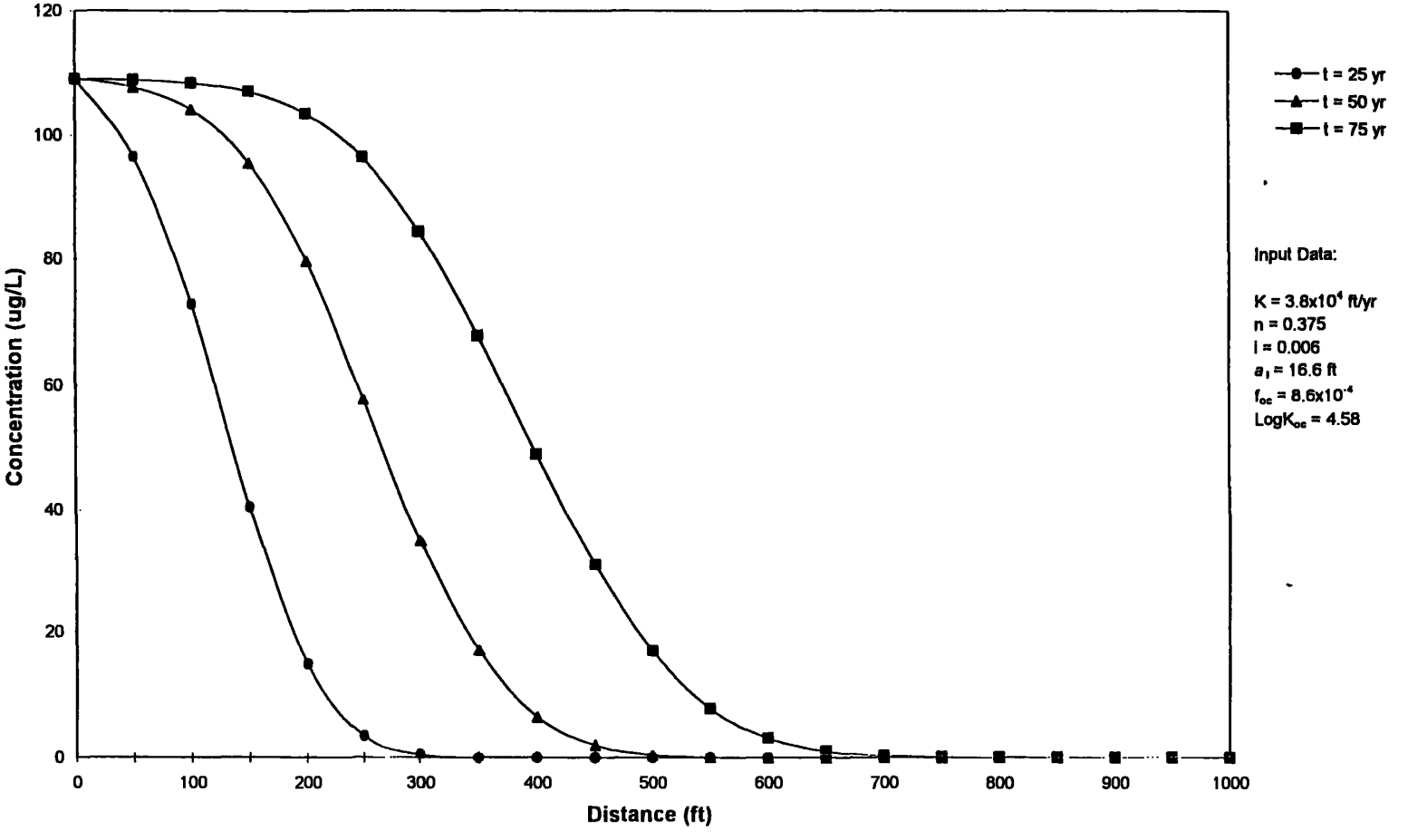
Breakthrough Curve
(Pyrene - North)



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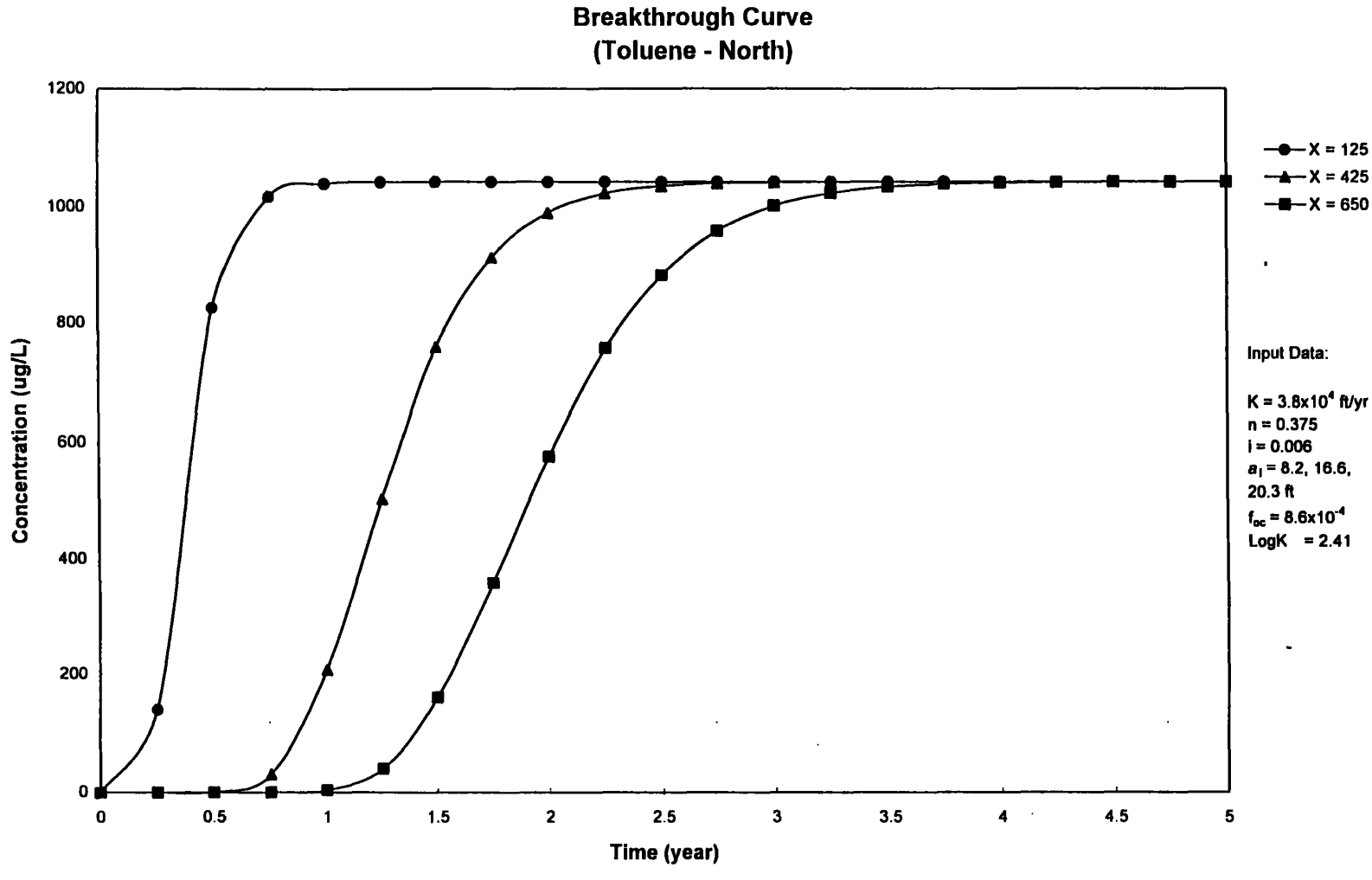
SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

TOLUENE

The remedial goal for toluene, as specified in the ROD, is 28 ug/l. The effective solubility for toluene is 1,040 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing toluene at a concentration equal to the ROD remedial goal to reach the hypothetical exposure endpoint (x=425 ft.) is less than one year.

A toluene concentration of 5 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an toluene concentration equal to the effective solubility (1,040 ug/l) in monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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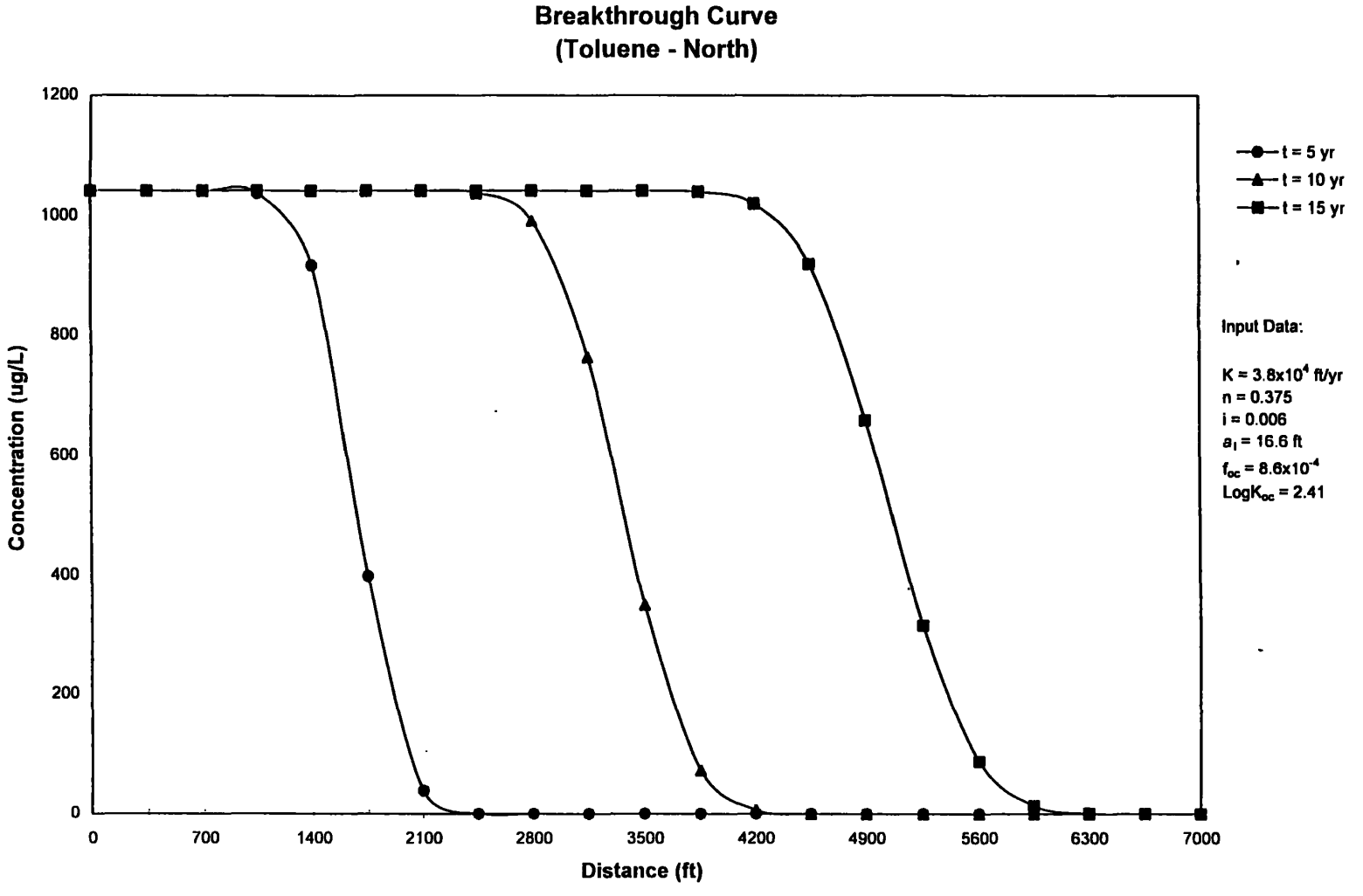

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SCENARIO 1A - NORTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

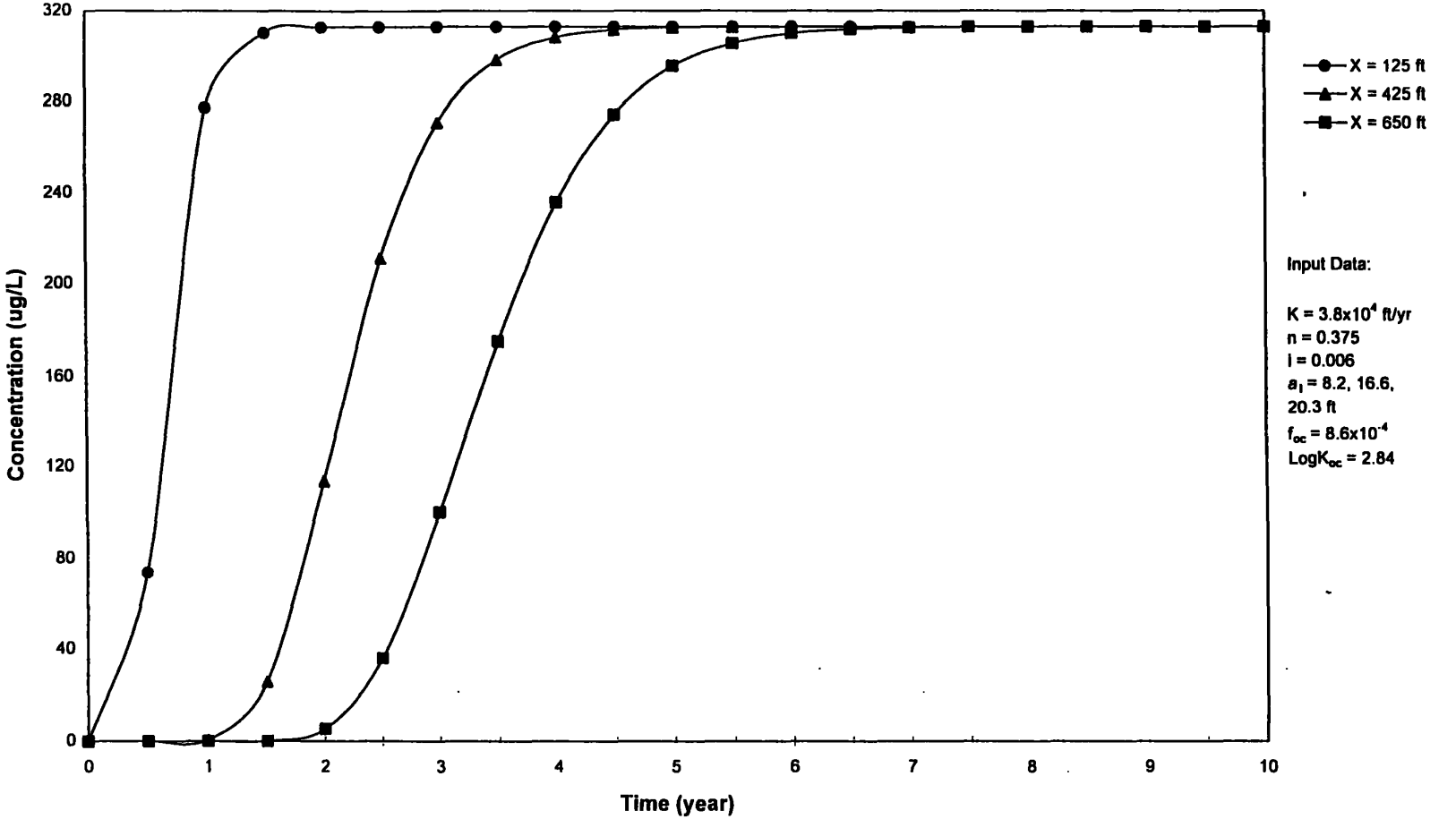
XYLENE

The remedial goal for xylene, as specified in the ROD, is 440 ug/l. The effective solubility for toluene (313 ug/l) is slightly less than the ROD goal. The concentration versus time graph of the model output indicates that the estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=425 ft.) is approximately 5 years.

A xylene concentration of 9 ug/l was measured in monitoring well (MW-01) located at a distance of approximately 260 feet downgradient of the potential source area during the most recent groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an xylene concentration equal to the effective solubility (313 ug/l) in monitoring well MW-01. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.

Breakthrough Curve
(Xylenes - North)



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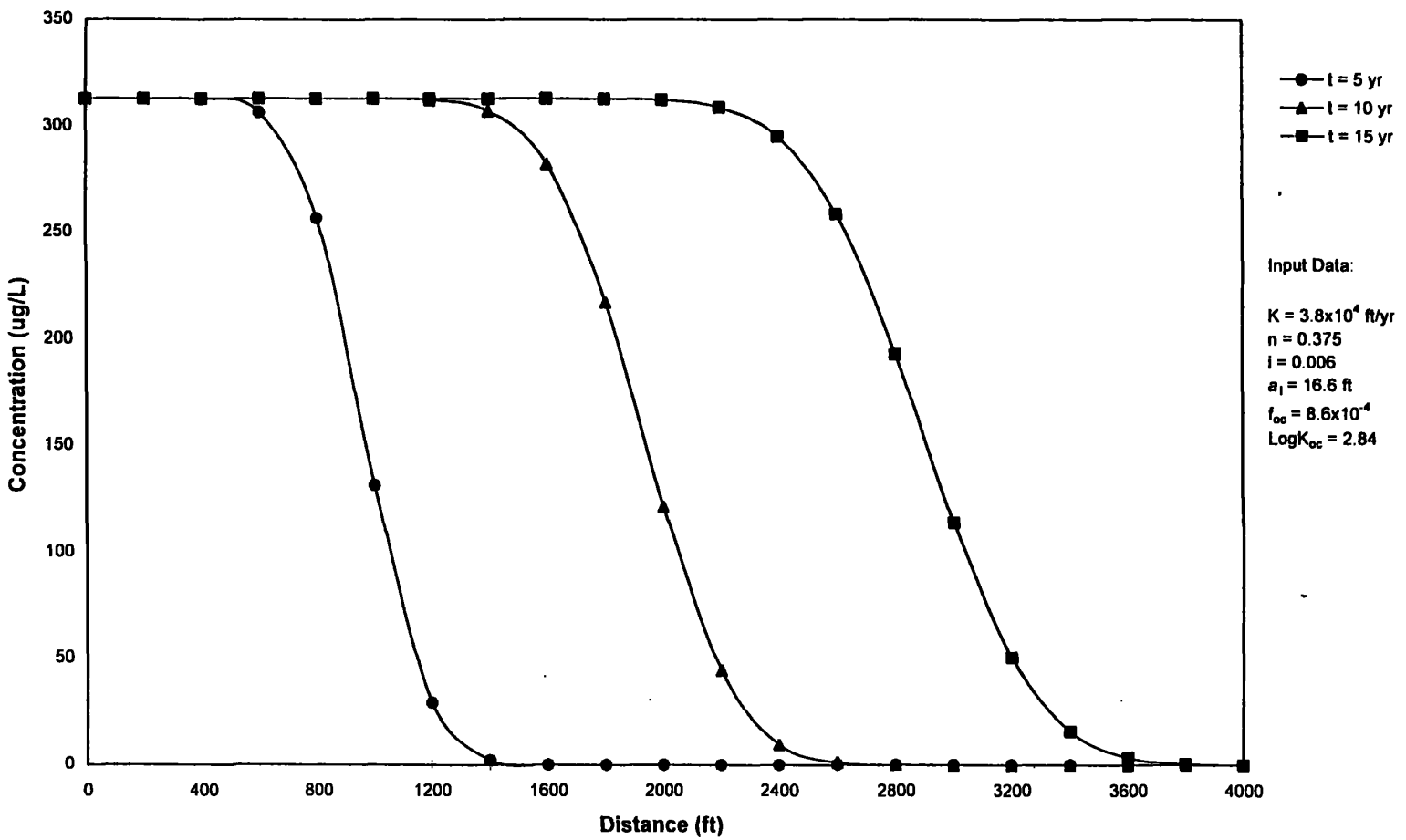
Breakthrough Curve
(Xylenes - North)



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APPENDIX C

SCENARIO 1A - WORST CASE SIMULATIONS (SOUTHERN AREA)

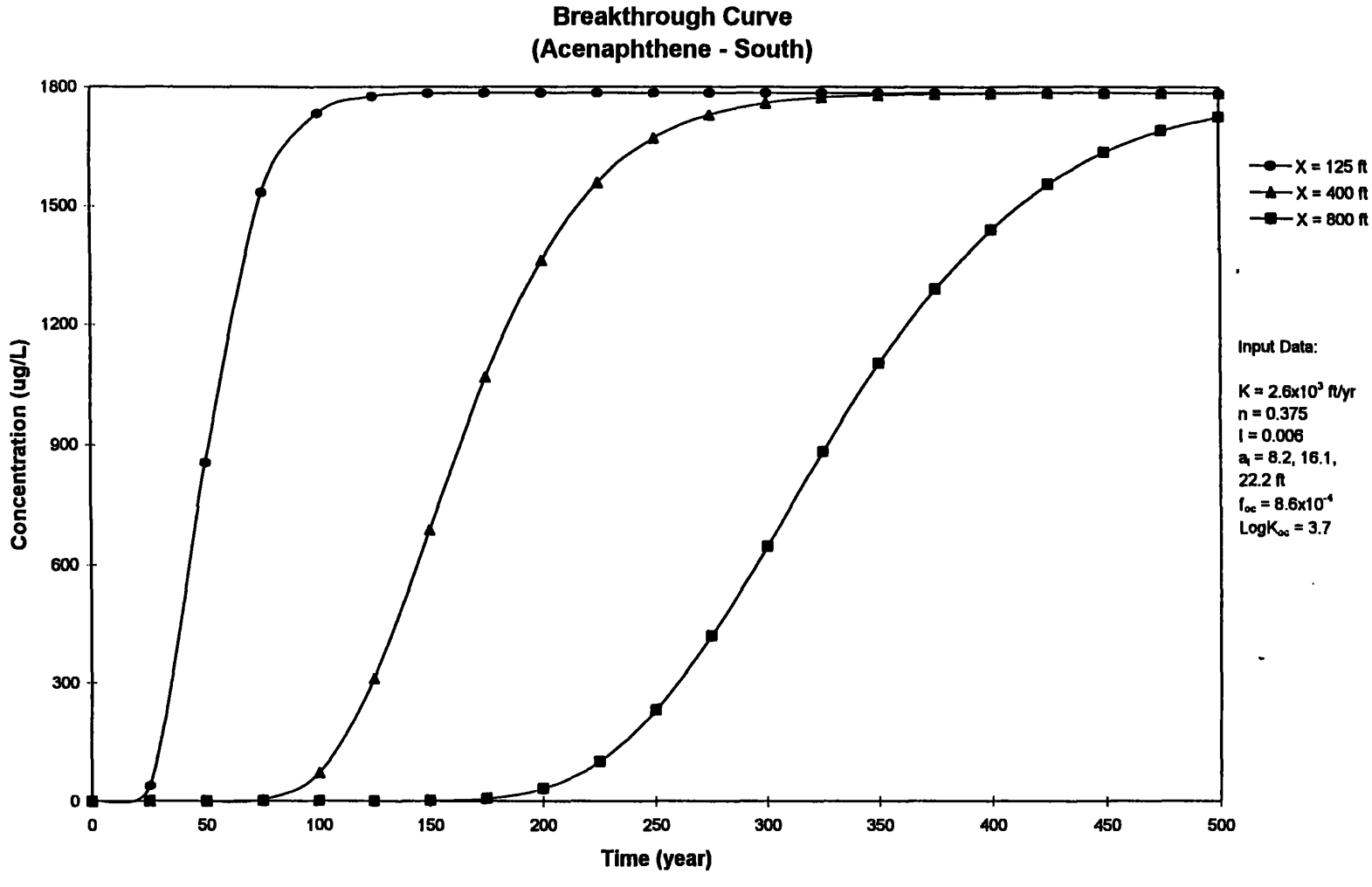
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

ACENAPHTHENE

No remedial goal for acenaphthene is specified in the ROD. The effective solubility for acenaphthene (1,790 ug/l) is slightly less than the TNRCC MSC (2,190 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 300 years.

A maximum acenaphthene concentration of 22 ug/l was measured in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an acenaphthene concentration for monitoring well MW-08 less than the actual concentration measured in the RI groundwater sample. This comparison of actual and predicted concentrations does not reflect the conservative nature of this scenario. Based on comparison of PAH constituent ratios in monitoring well MW-08 to those observed in the on-Site monitoring wells, it is possible that the PAH constituents measured in monitoring well MW-08 during the RI may originate from a source other than the South Cavalcade Superfund Site.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will not be further evaluated in the southern area.



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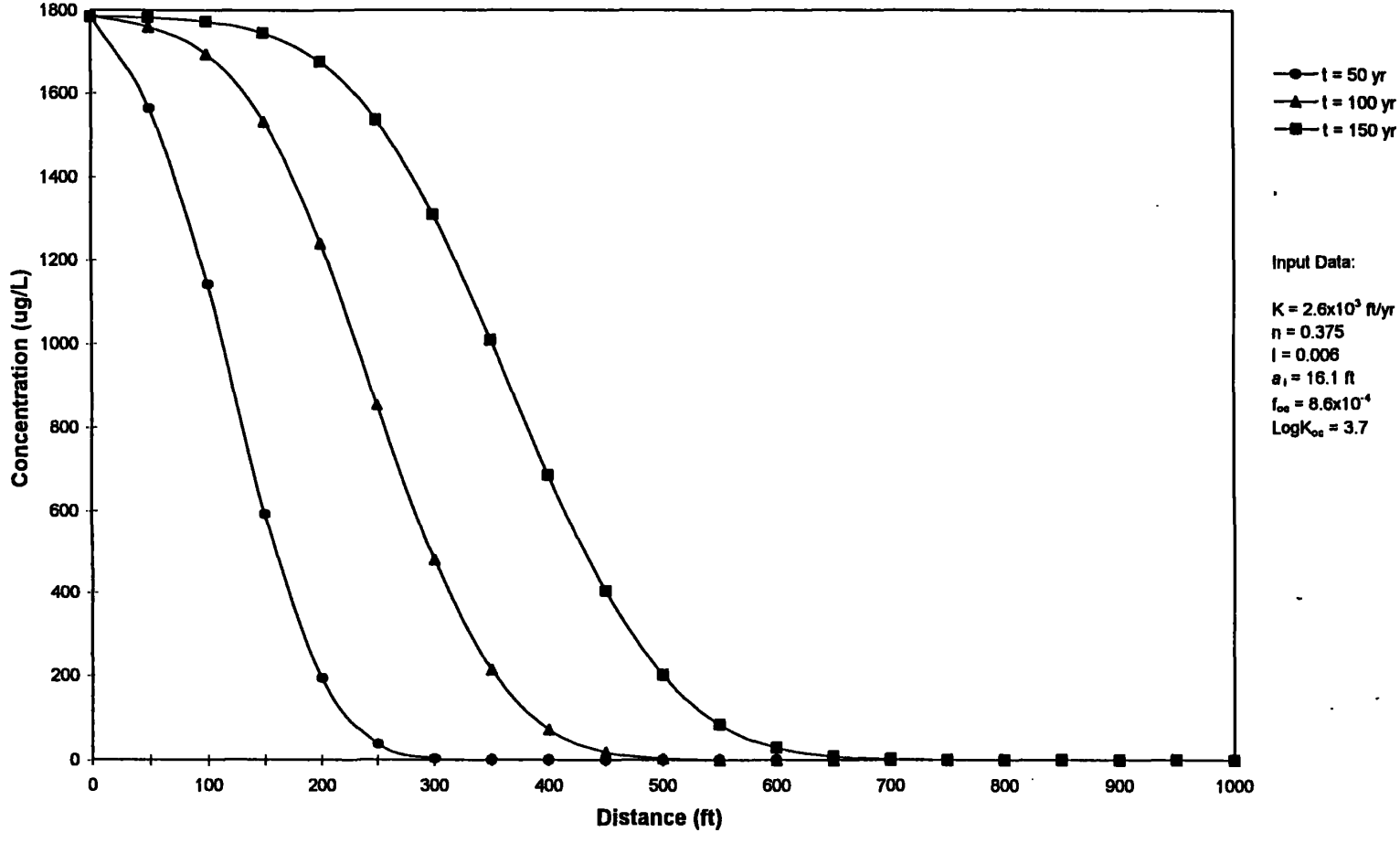
Breakthrough Curve
(Acenaphthene - South)



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SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

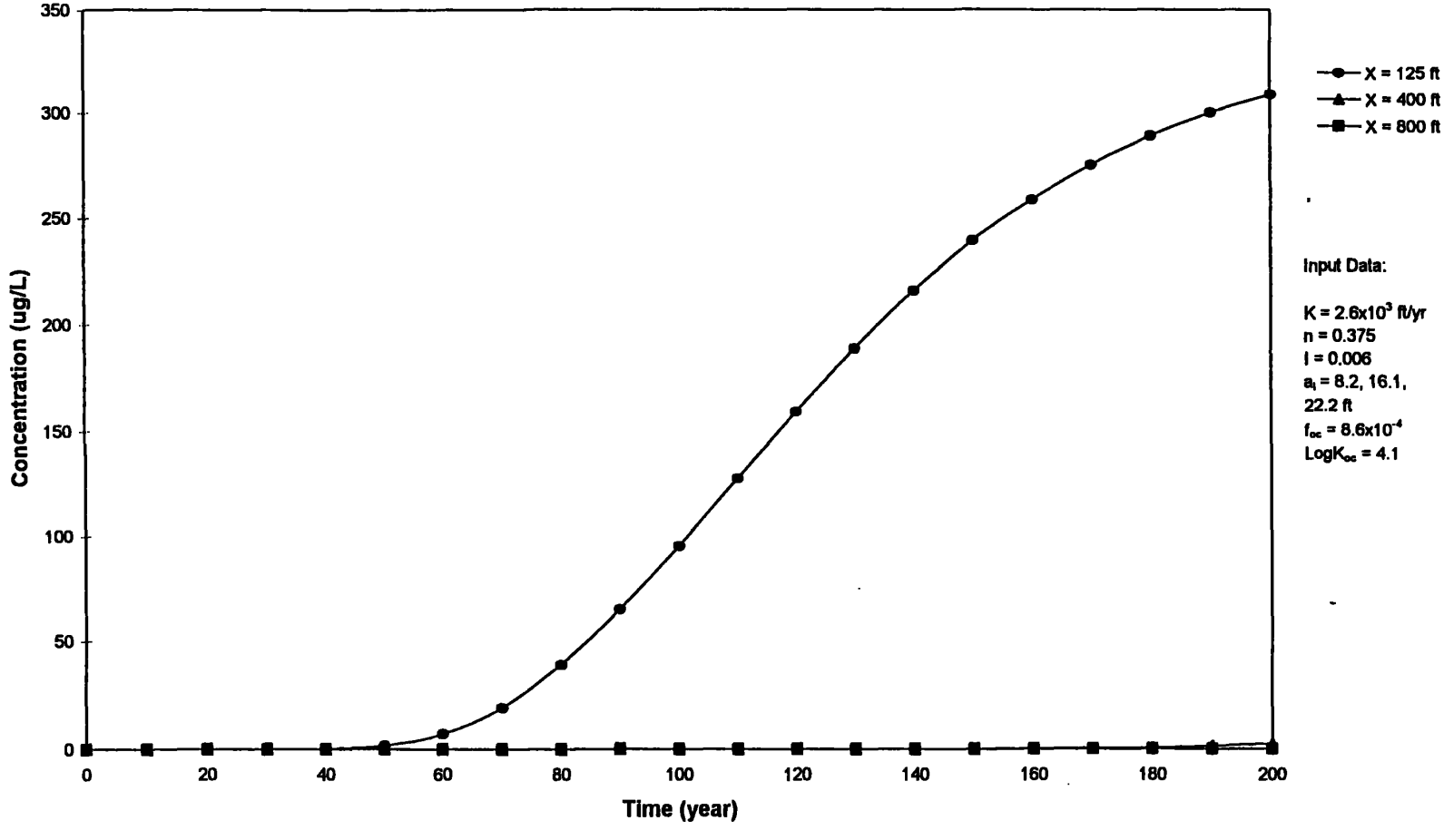
ANTHRACENE

No remedial goal for anthracene is specified in the ROD. The effective solubility for anthracene (339 ug/l) is much less than the TNRCC MSC (11,100 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 300 years.

An estimated anthracene concentration of 7 ug/l was measured in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during both RI groundwater sampling events. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts a comparable concentration for monitoring well MW-08. This comparison of actual and predicted concentrations does not reflect the conservative nature of this scenario. Based on comparison of PAH constituent ratios in monitoring well MW-08 to those observed in the on-Site monitoring wells, it is possible that the PAH constituents measured in monitoring well MW-08 during the RI may originate from a source other than the South Cavalcade Superfund Site.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point, this parameter will not be further evaluated.

Breakthrough Curve
(Anthracene - South)



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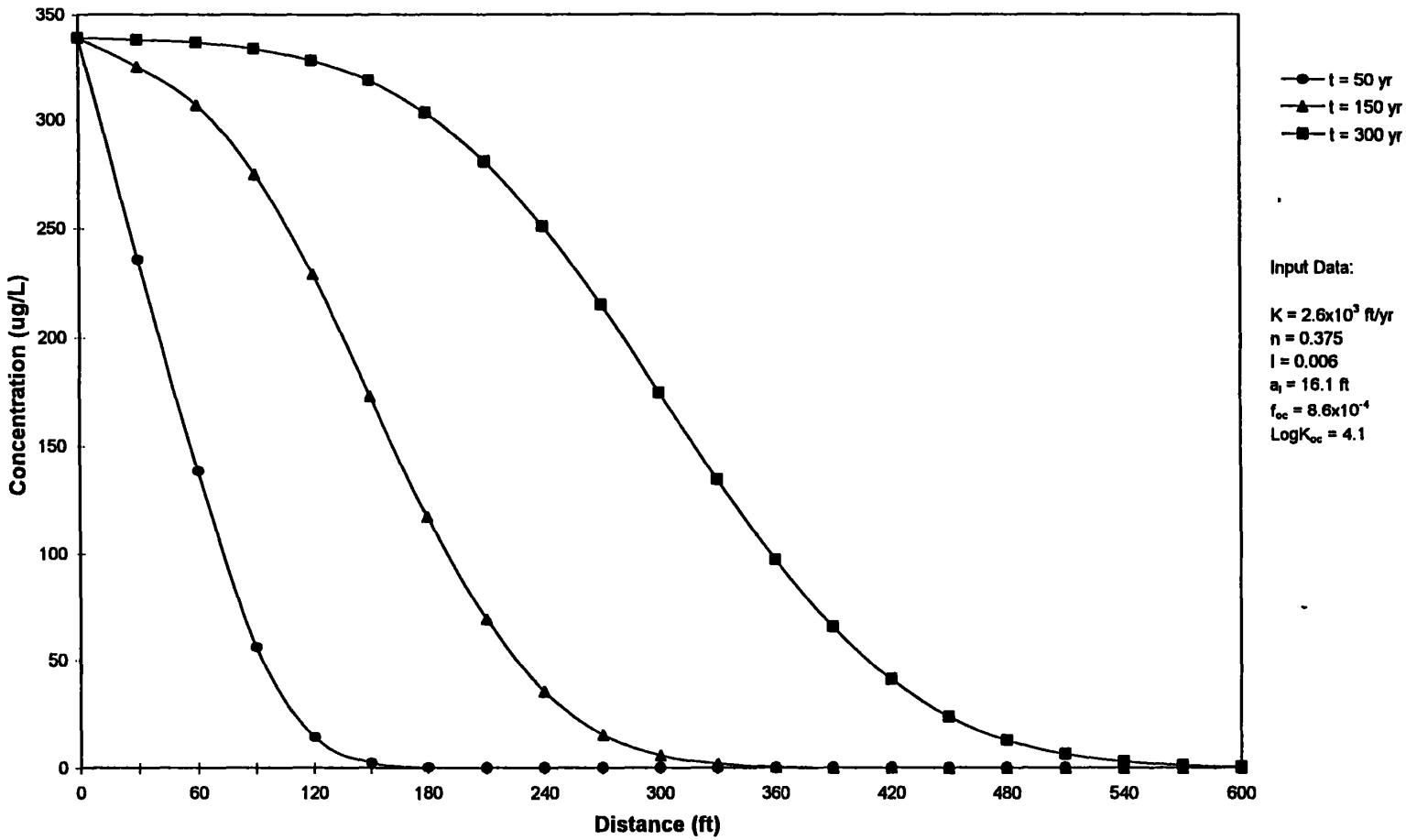
Breakthrough Curve
(Anthracene - South)



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SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

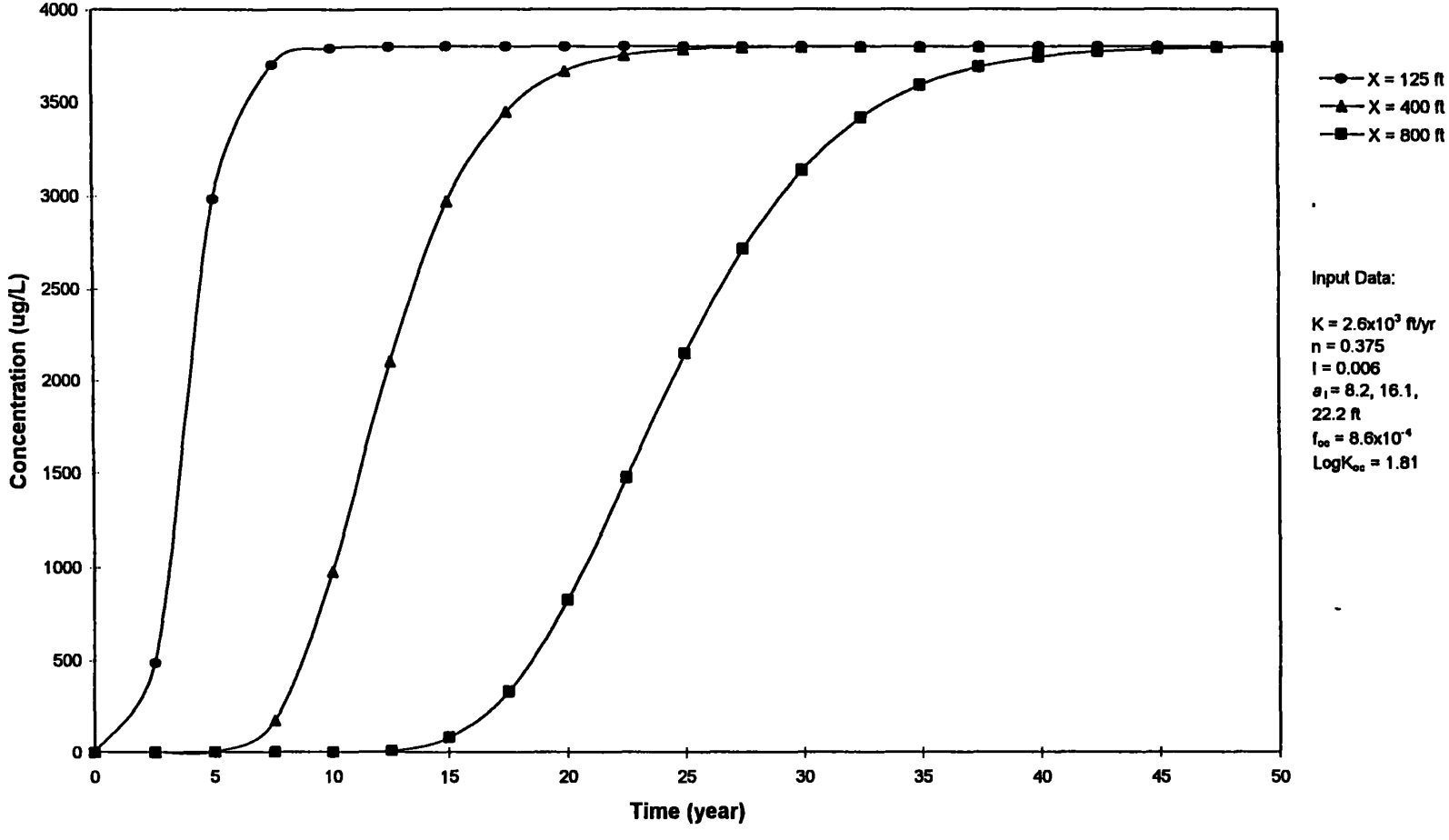
BENZENE

The remedial goal for benzene, as specified in the ROD, is 5 ug/l. The effective solubility for benzene is 3,800 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing benzene at a concentration equal to the ROD remedial goal to reach the hypothetical exposure endpoint (x=400 ft.) of approximately 5 years.

Benzene was not detected in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts a benzene concentration equal to the effective solubility of 3,800 ug/l in monitoring well MW-08. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios for the southern area.

Breakthrough Curve
(Benzene - South)



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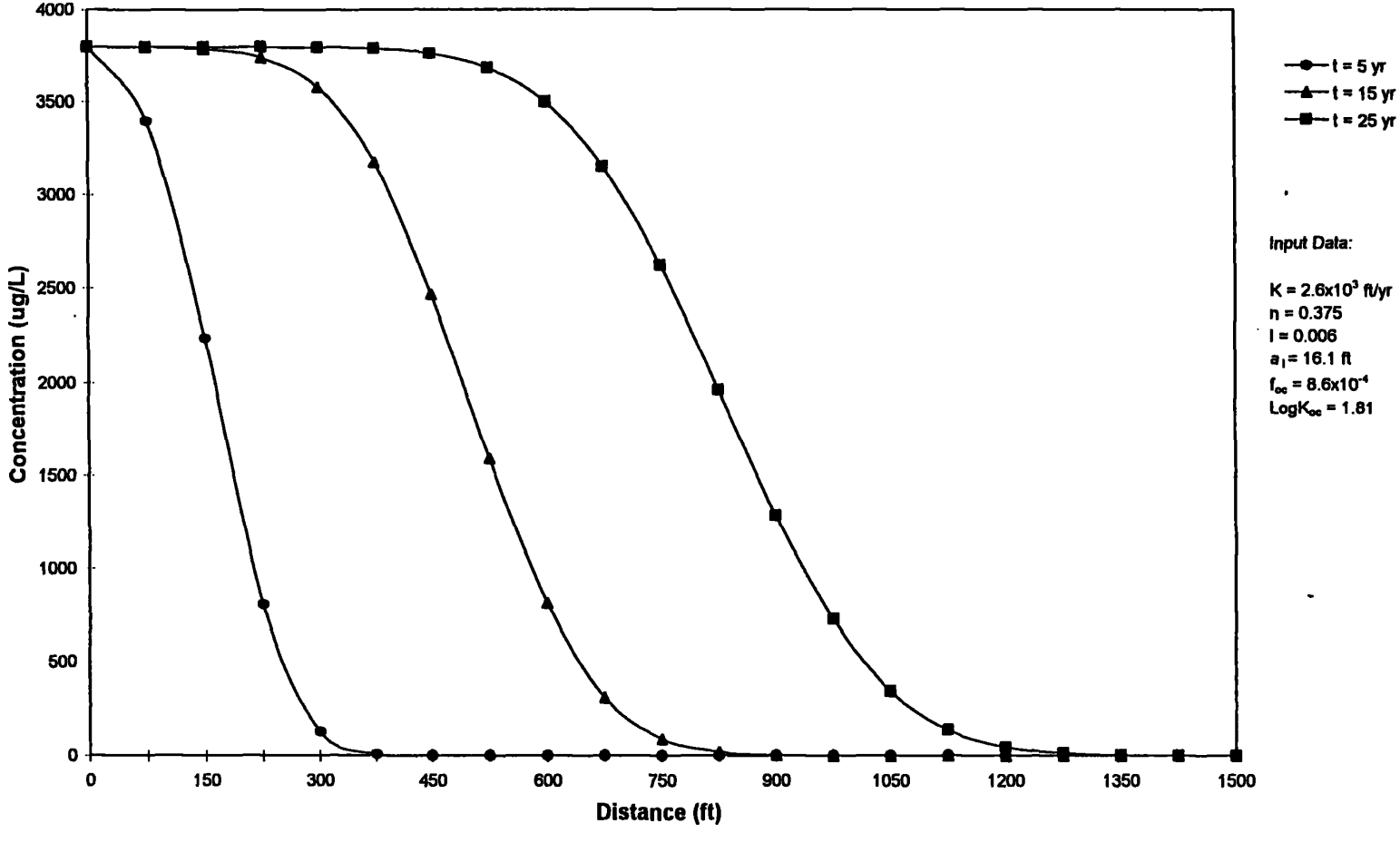
Breakthrough Curve
(Benzene - South)



Input Data:

K = 2.6×10^3 ft/yr
n = 0.375
I = 0.006
a_l = 16.1 ft
f_{oc} = 8.6×10^{-4}
LogK_{oc} = 1.81

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SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

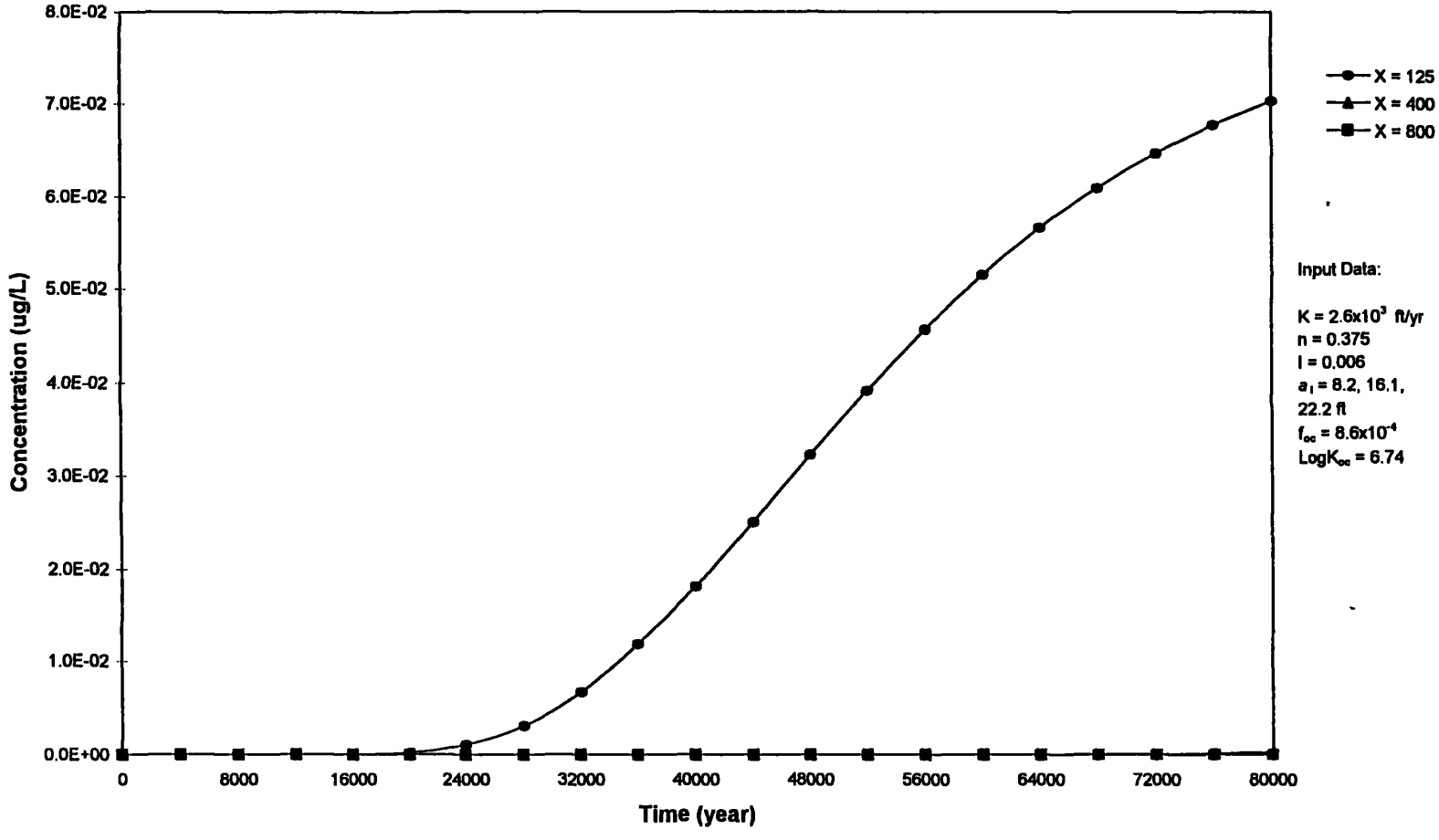
BENZO(a)PYRENE

Benzo(a)pyrene is considered a potentially carcinogenic PAH. The remedial goal for potentially carcinogenic PAHs as specified in the ROD is no detection. As a result, the Practical Quantitation Limit for this constituent (10 ug/l) is used as the remedial goal in this assessment. The effective solubility for benzo(a)pyrene (0.08 ug/l) is much less than the remedial goal. The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 80,000 years.

Benzo(a)pyrene was not detected in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Therefore, the simulated results for this constituent are consistent with the actual field data.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will be not further evaluated in the southern area.

Breakthrough Curve
(Benzo(a)pyrene - South)



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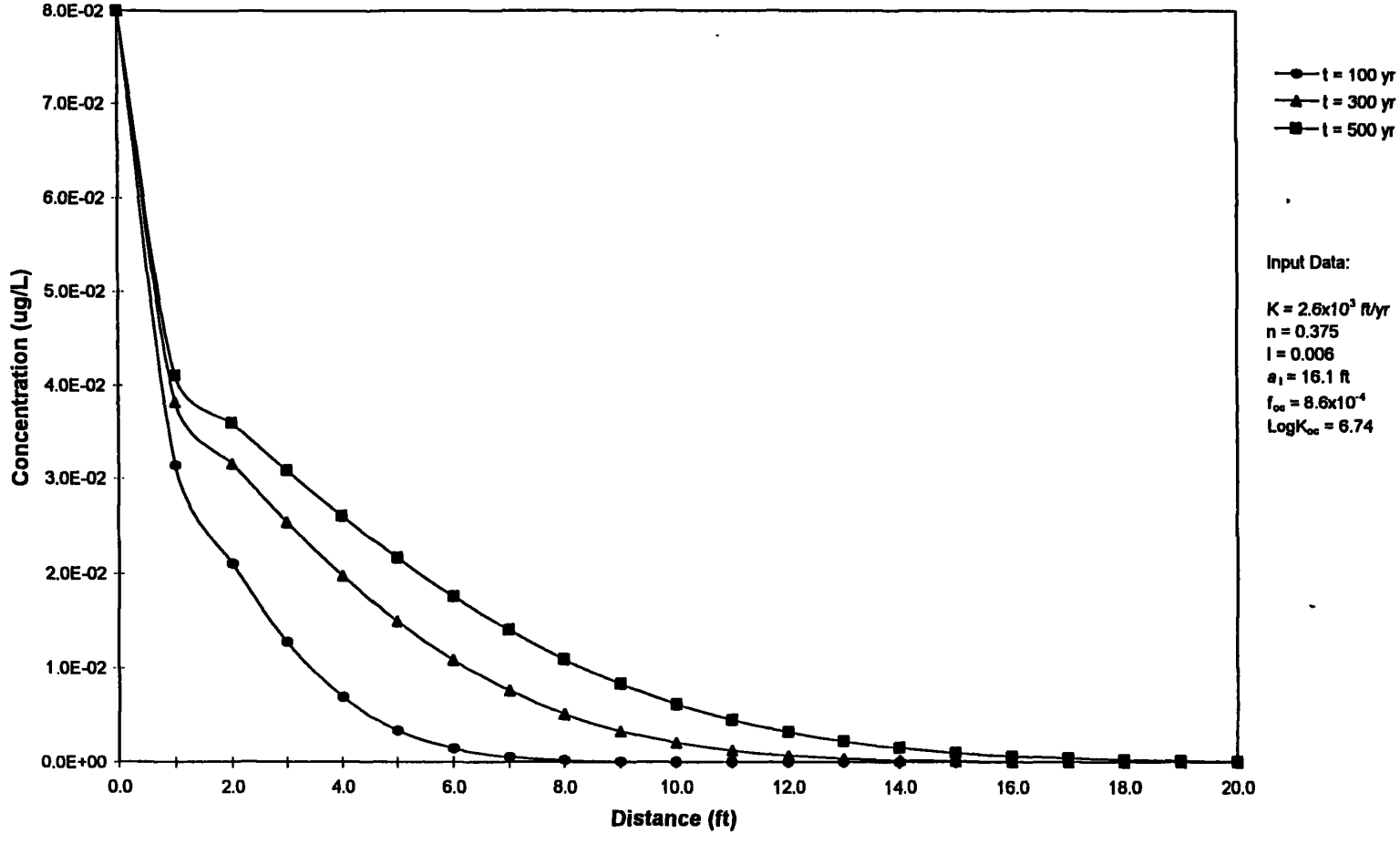
Breakthrough Curve
(Benzo(a)pyrene - South)



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SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

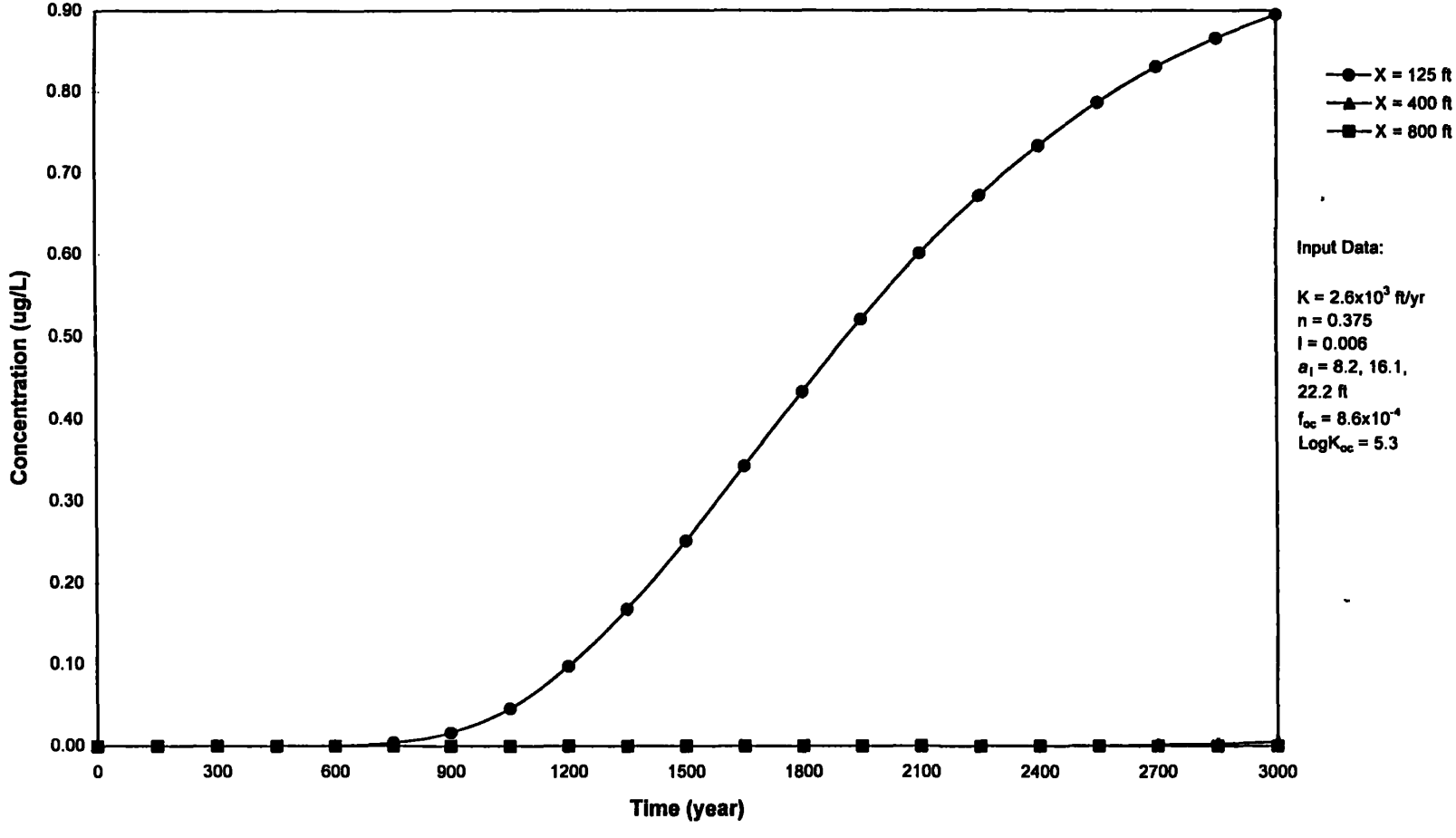
CHRYSENE

Chrysene is considered a potentially carcinogenic PAH. The remedial goal for potentially carcinogenic PAHs as specified in the ROD is no detection. As a result, the Practical Quantitation Limit for this constituent (10 ug/l) is used as the remedial goal in this assessment. The effective solubility for chrysene (1.0 ug/l) is less than the remedial goal. The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 3,000 years.

Chrysene was not detected in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Therefore, the simulated results for this constituent are consistent with the actual field data.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will be not further evaluated in the southern area.

Breakthrough Curve
(Chrysene - South)



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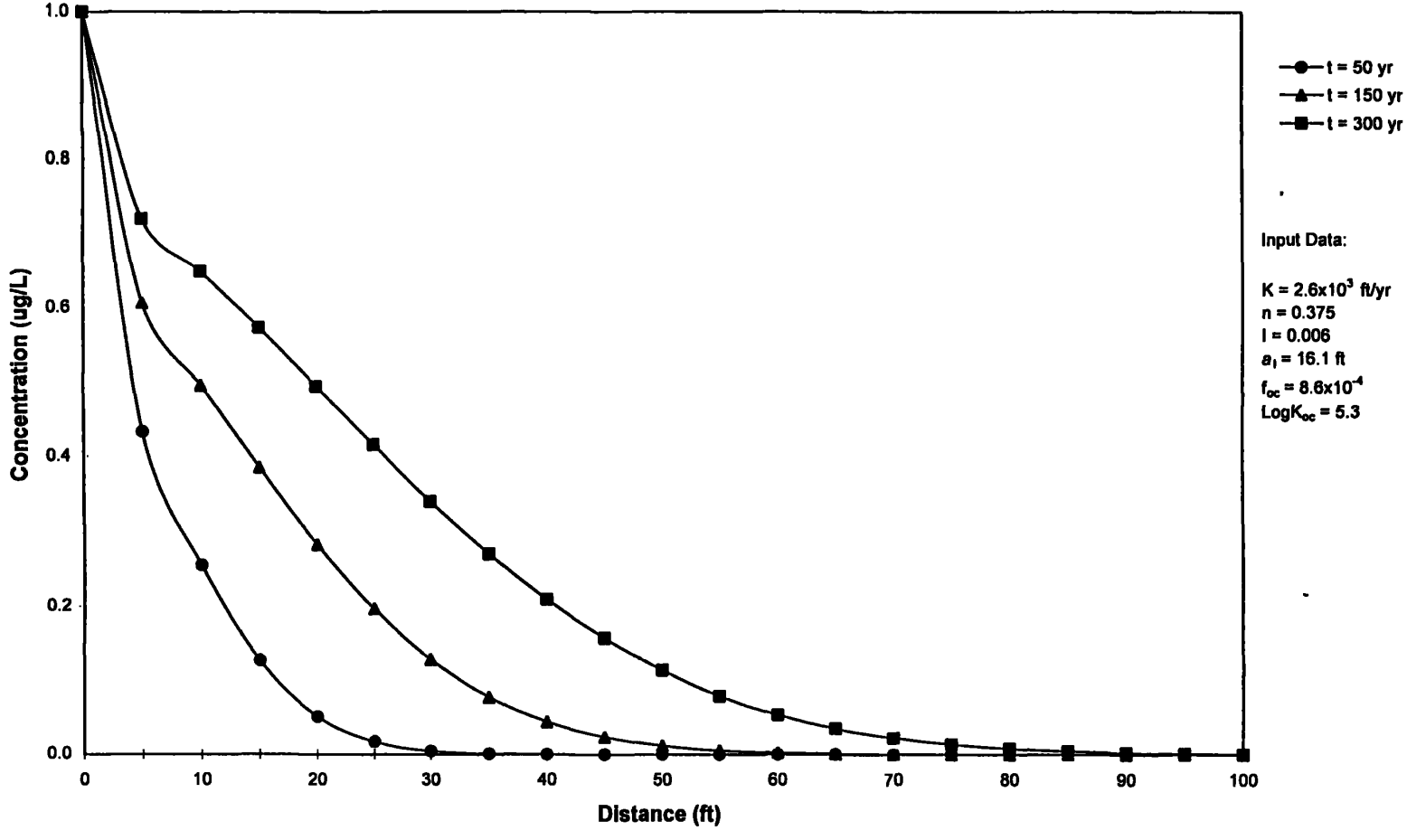
Breakthrough Curve
(Chrysene - South)



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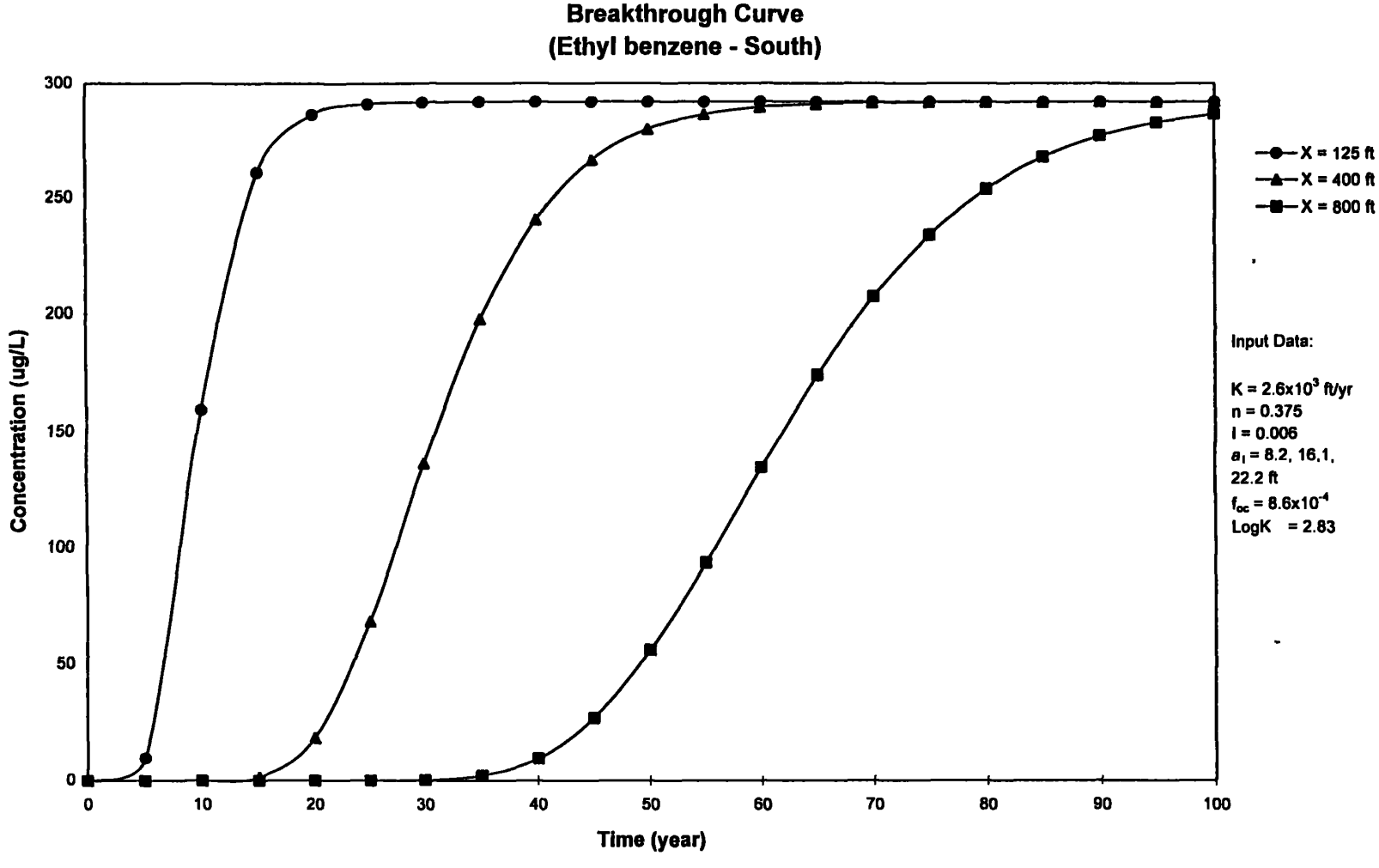
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

ETHYLBENZENE

The remedial goal for ethylbenzene, as specified in the ROD, is 142 ug/l. The effective solubility for ethylbenzene is 292 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing ethylbenzene at a concentration equal to the ROD remedial goal to reach the hypothetical exposure endpoint (x=400 ft.) of approximately 30 years.

Ethylbenzene was not detected in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an ethylbenzene concentration of more than 200 ug/l in monitoring well MW-08. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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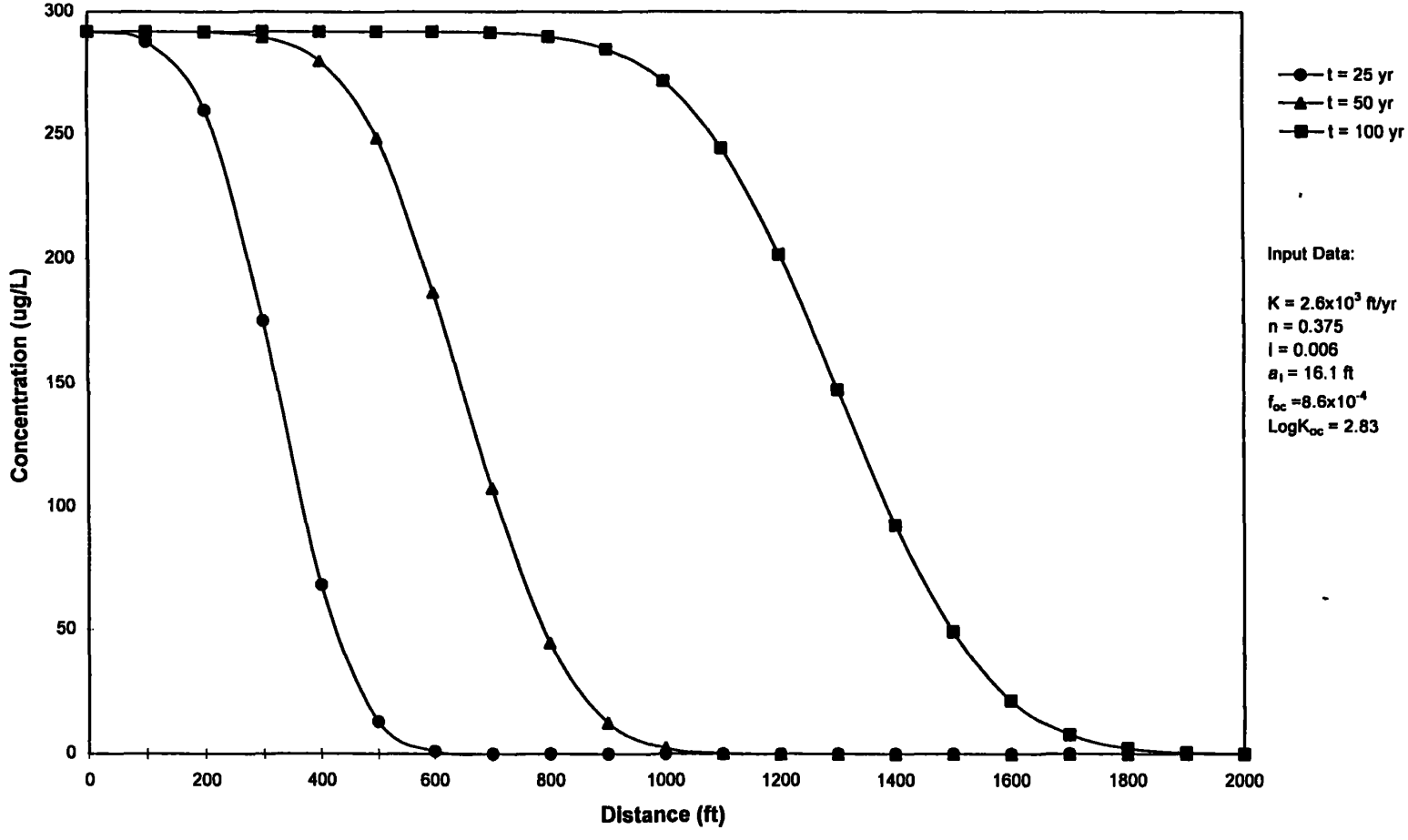
Breakthrough Curve
(Ethyl benzene - South)



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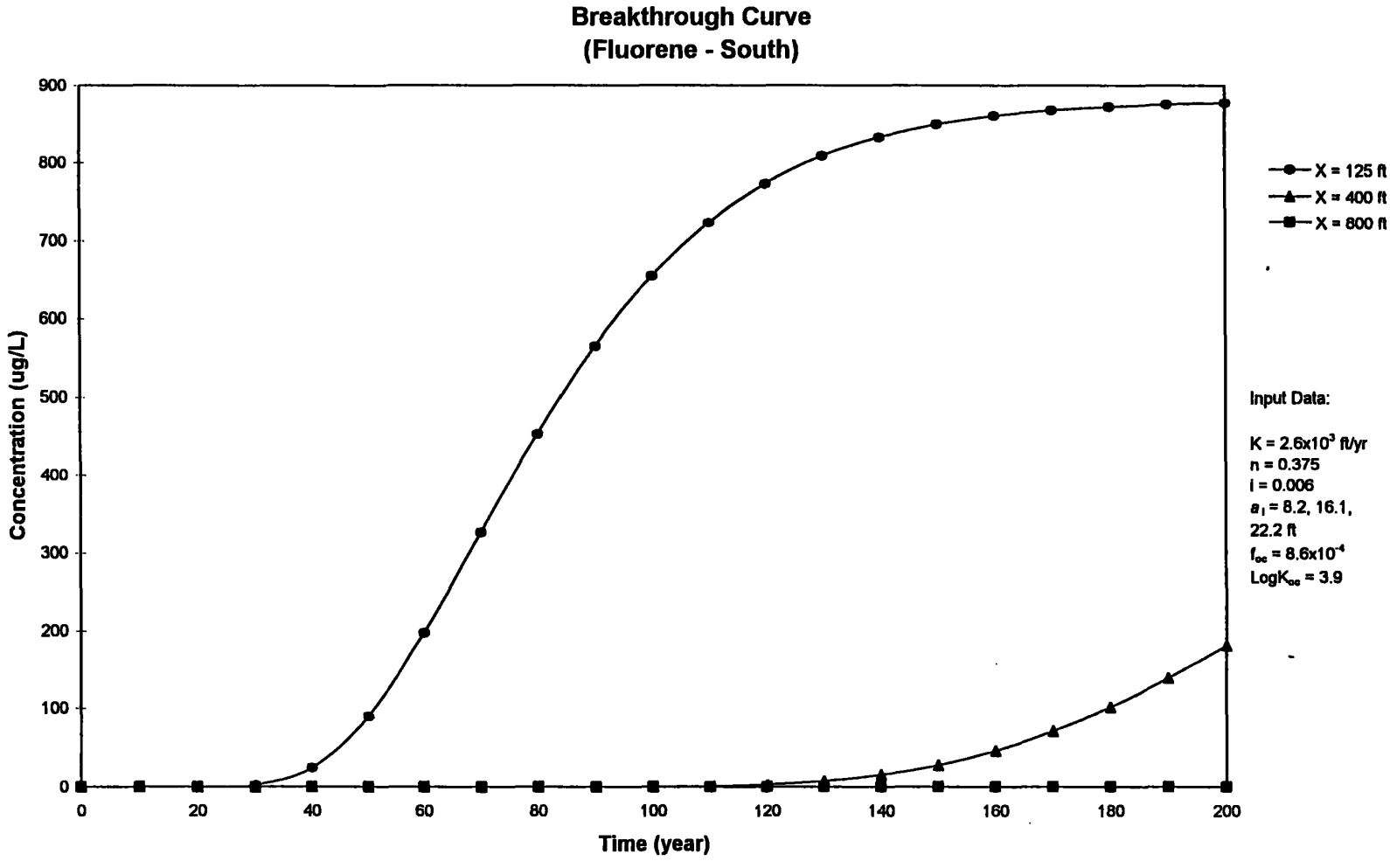
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

FLUORENE

No remedial goal for fluorene is specified in the ROD. The effective solubility for fluorene (881 ug/l) is less than the TNRCC MSC (1,460 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 300 years.

A maximum fluorene concentration of 20 ug/l was measured in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. The conservative model simulation predicts that it would take more than 120 years for detectable levels of fluorene to migrate the distance from the source area to the location of monitoring well MW-08. This comparison of actual and predicted concentrations does not reflect the conservative nature of this scenario. Based on comparison of PAH constituent ratios in monitoring well MW-08 to those observed in the on-Site monitoring wells, it is possible that the PAH constituents measured in monitoring well MW-08 during the RI may originate from a source other than the South Cavalcade Superfund Site.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will be not further evaluated in the southern area.



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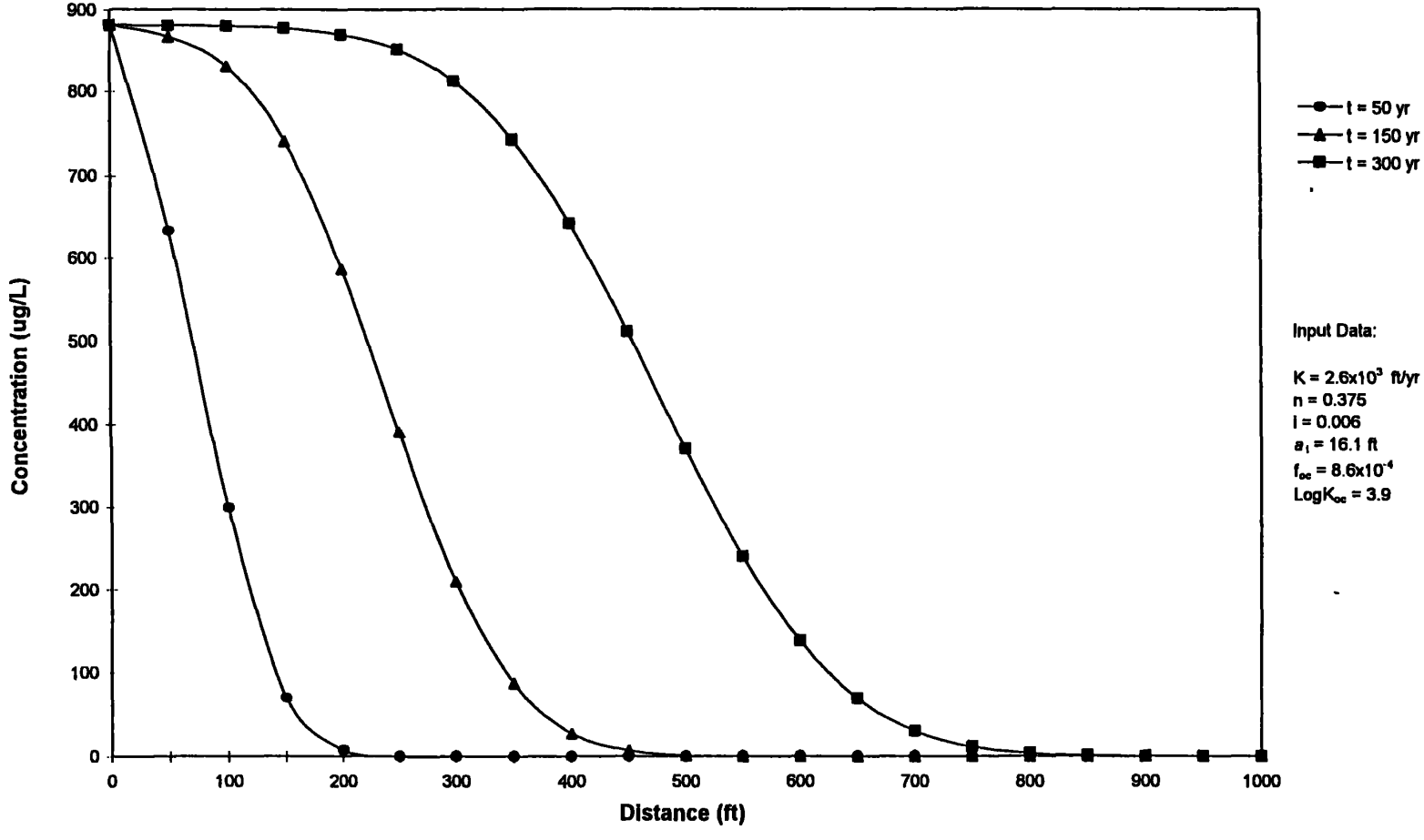
Breakthrough Curve
(Fluorene - South)



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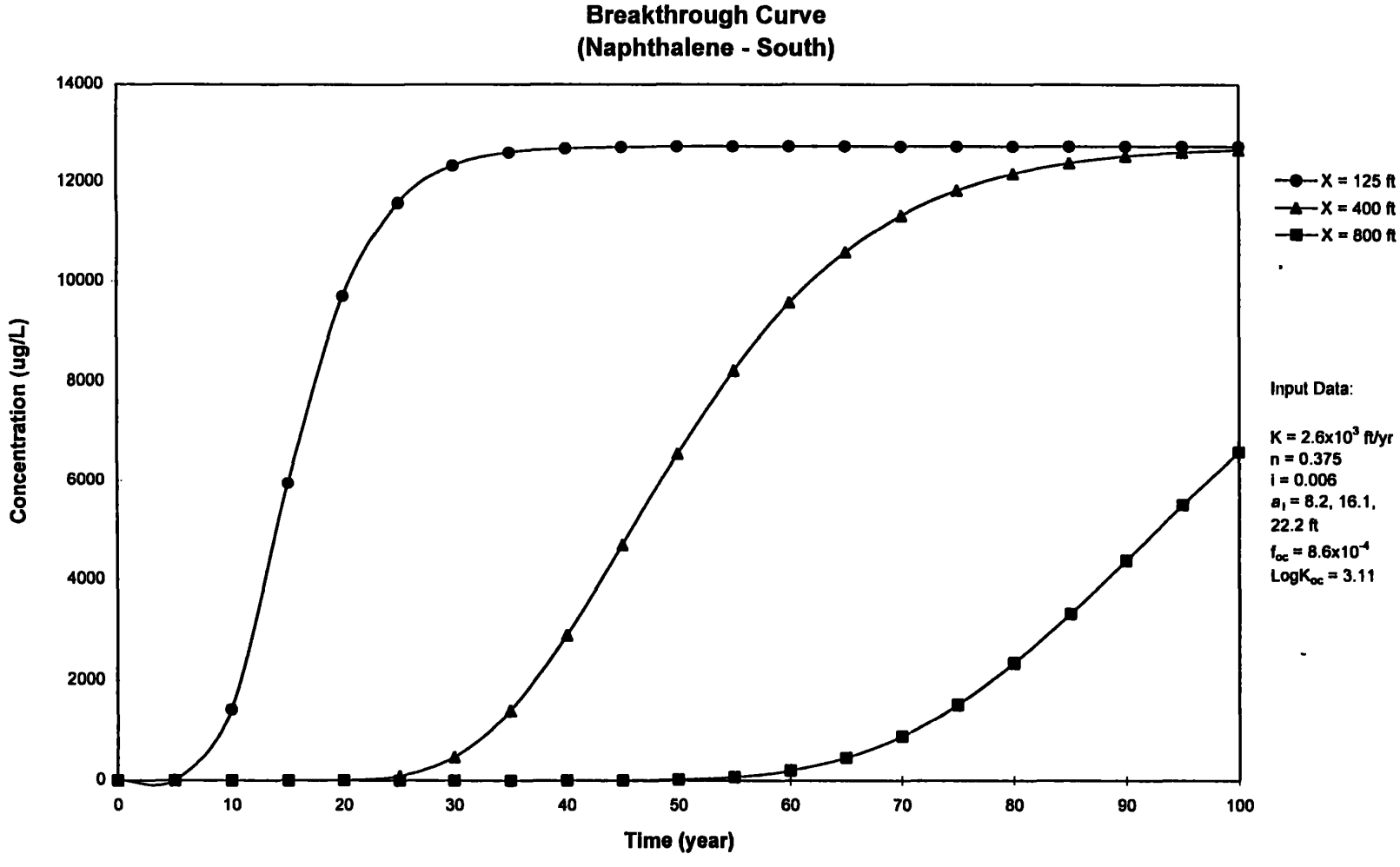
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

NAPHTHALENE

No remedial goal for naphthalene is specified in the ROD. The effective solubility for naphthalene is 12,700 ug/l and the TNRCC MSC is 1,460 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing naphthalene at a concentration equal to the TNRCC MSC to reach the hypothetical exposure endpoint (x=400 ft.) of approximately 35 years.

A maximum naphthalene concentration of 24 ug/l was measured in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an naphthalene concentration of more than 1,600 ug/l in monitoring well MW-08. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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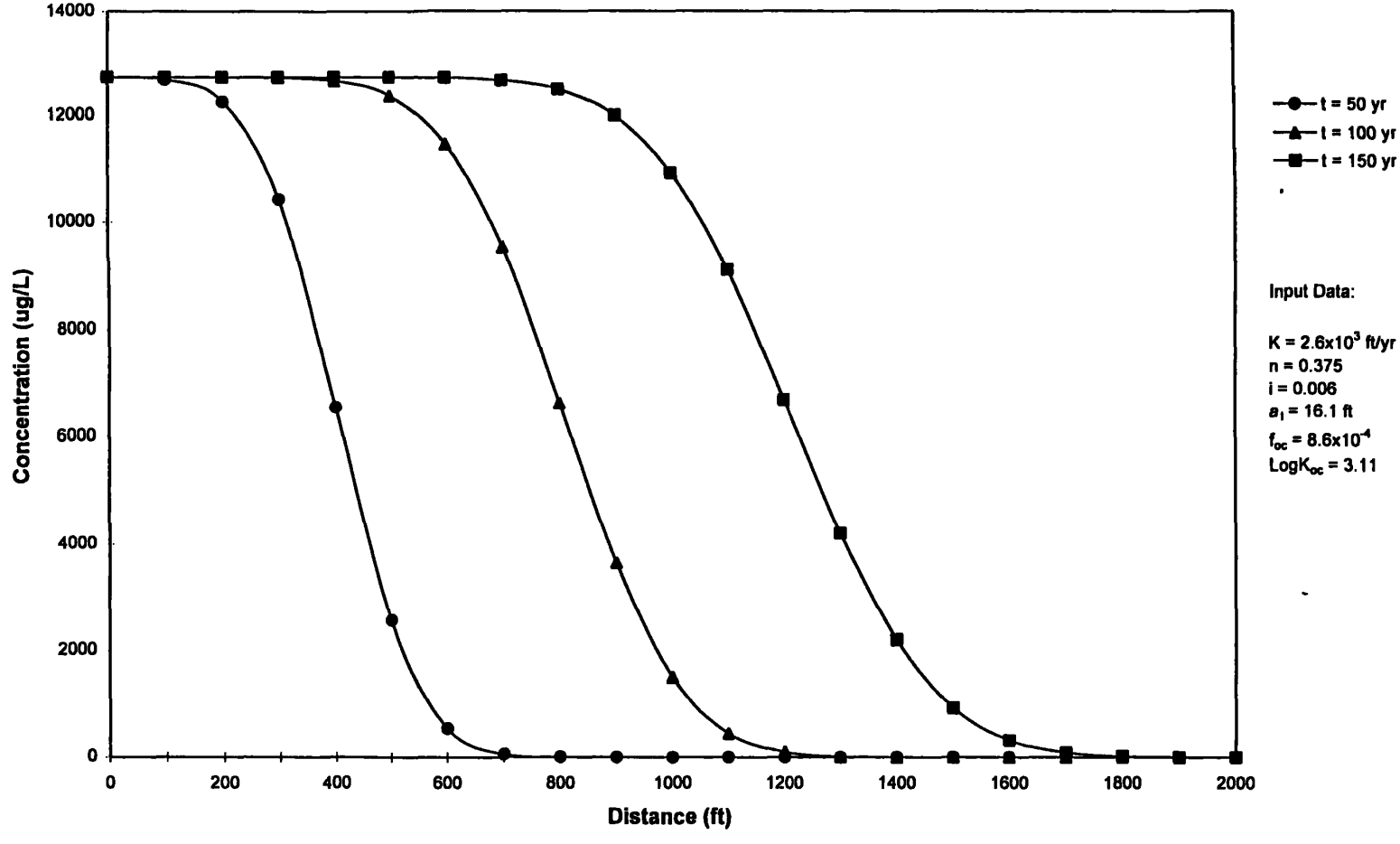
Breakthrough Curve
(Naphthalene - South)



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SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

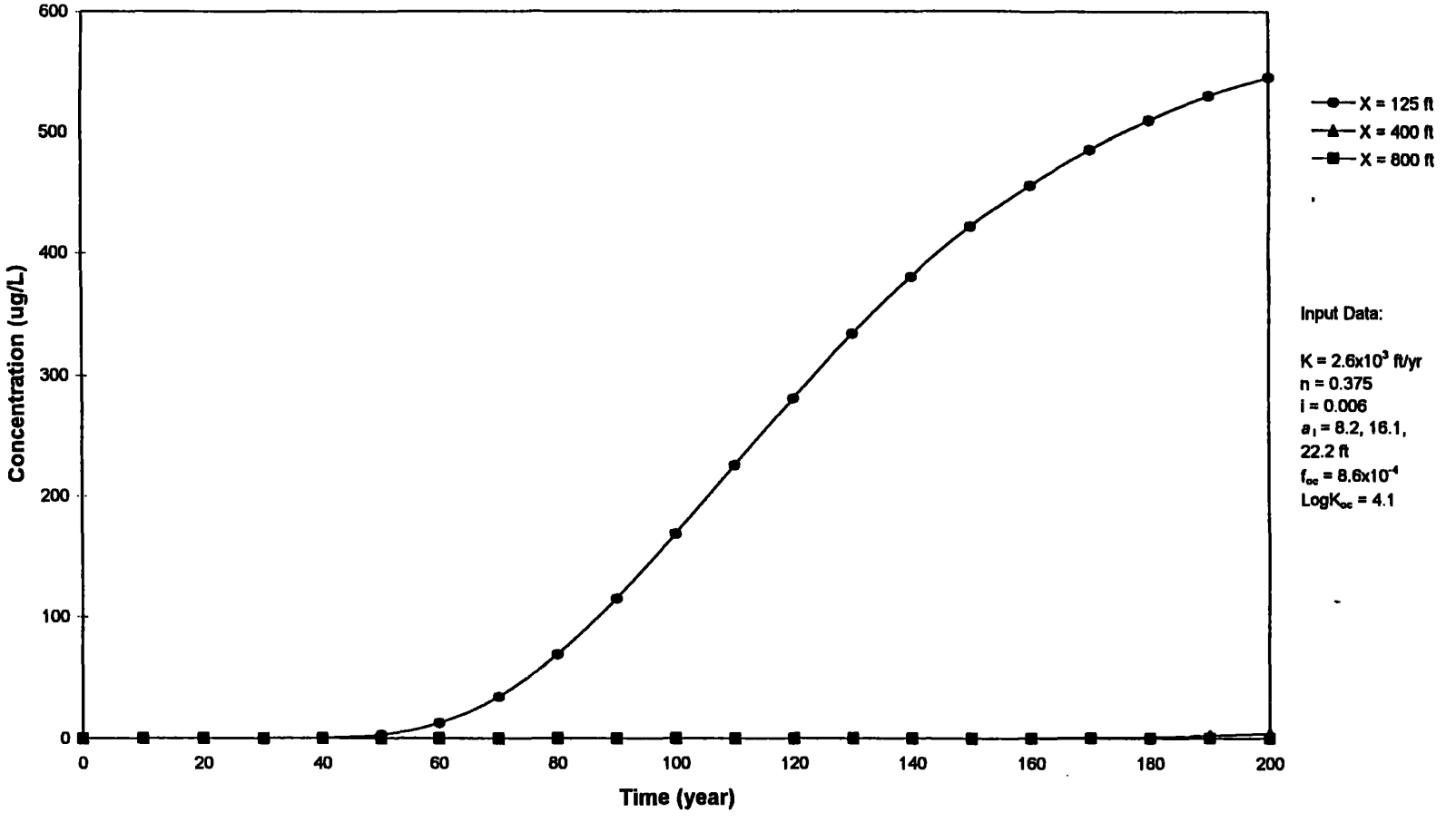
PHENANTHRENE

No remedial goal for phenanthrene is specified in the ROD. The effective solubility for phenanthrene (598 ug/l) is much less than the TNRCC MSC (11,100 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 300 years.

A maximum phenanthrene concentration of 57 ug/l was measured in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Assuming that the source area existed during the year that plant operations were begun, the conservative model simulation predicts non-detectable phenanthrene concentrations in monitoring well MW-08 during the RI . This comparison of actual and predicted concentrations does not reflect the conservative nature of this scenario because the actual concentration determined through laboratory analysis are greater than the simulated concentration. Based on comparison of PAH constituent ratios in monitoring well MW-08 to those observed in the on-Site monitoring wells, it is possible that the PAH constituents measured in monitoring well MW-08 during the RI may originate from a source other than the South Cavalcade Superfund Site.

Based on the estimated time necessary for the advective front to migrate to the hypothetical future exposure point, this parameter will not be evaluated further under the less conservative scenarios.

Breakthrough Curve
(Phenanthrene - South)



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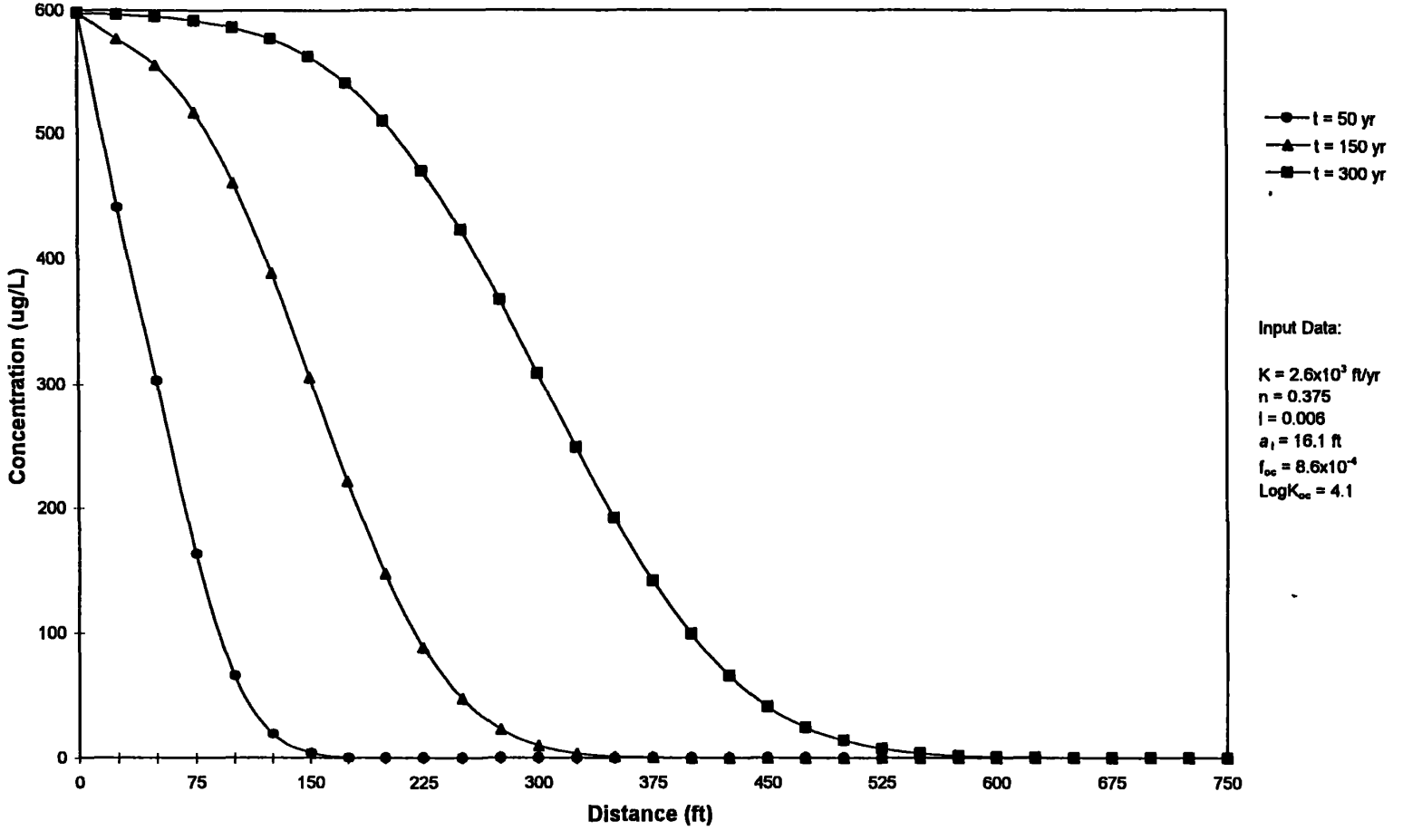
Breakthrough Curve
(Phenanthrene - South)



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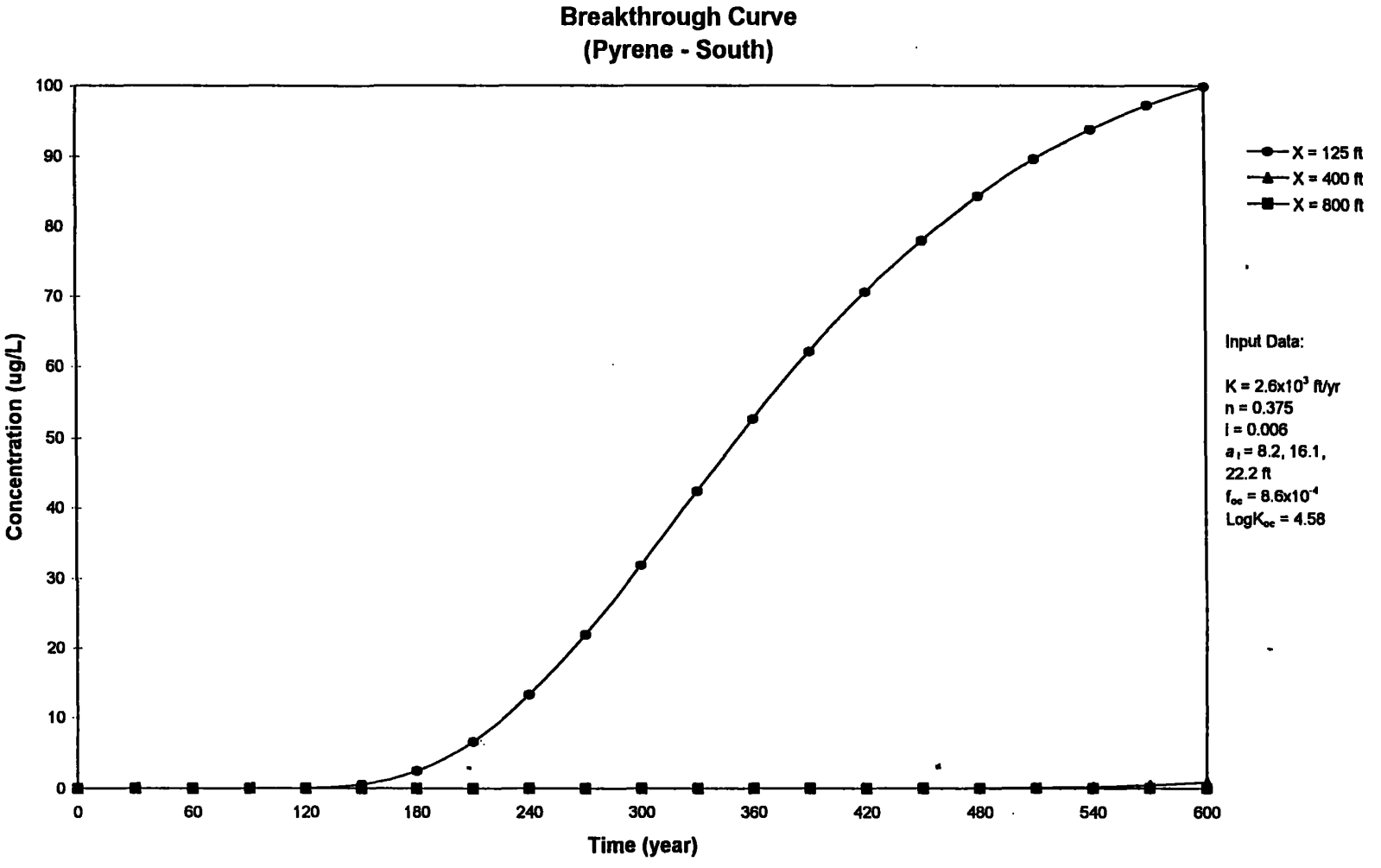
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

PYRENE

No remedial goal for pyrene is specified in the ROD. The effective solubility for pyrene (109 ug/l) is less than the TNRCC MSC (1,110 ug/l). The concentration versus time graph of the model output indicates an estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) of more than 600 years.

A maximum estimated pyrene concentration of 15 ug/l was measured in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling events. Assuming that the source area existed during the year that plant operations were begun, the conservative model simulation predicts a pyrene concentration less than the concentration measured in monitoring well MW-08. This comparison of actual and predicted concentrations does not reflect the conservative nature of this scenario because the actual concentration determined through laboratory analysis is greater than the simulated concentration. Based on comparison of PAH constituent ratios in monitoring well MW-08 to those observed in the on-Site monitoring wells, it is possible that the PAH constituents measured in monitoring well MW-08 during the RI may originate from a source other than the South Cavalcade Superfund Site.

Due to the simulated time necessary for the advective front to reach the hypothetical future exposure point and the conservative nature of this simulation, this parameter will be not further evaluated.



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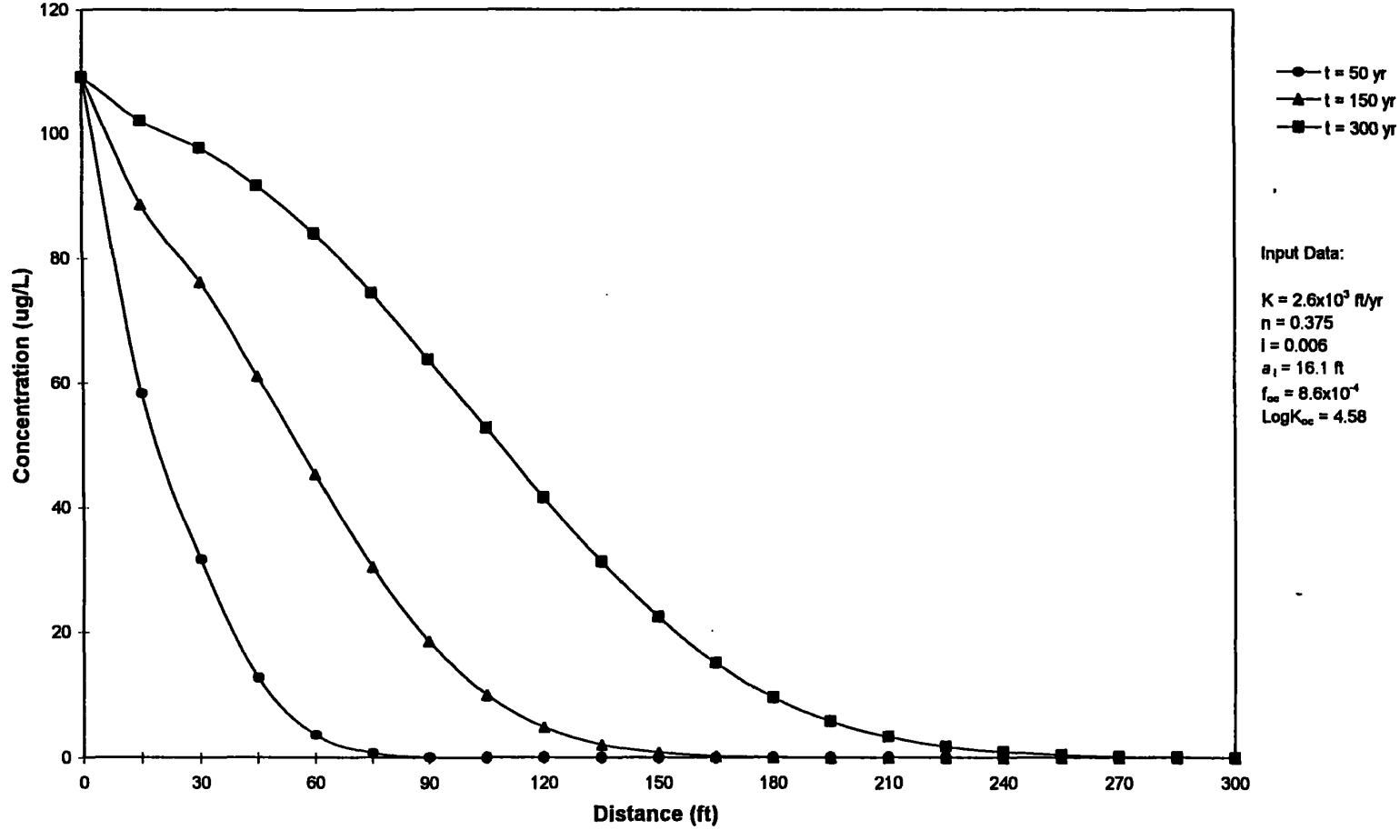
Breakthrough Curve
(Pyrene - South)



Input Data:

K = 2.6×10^{3} ft/yr
n = 0.375
I = 0.006
a_l = 16.1 ft
f_{oc} = 8.6×10^{-4}
LogK_{oc} = 4.58

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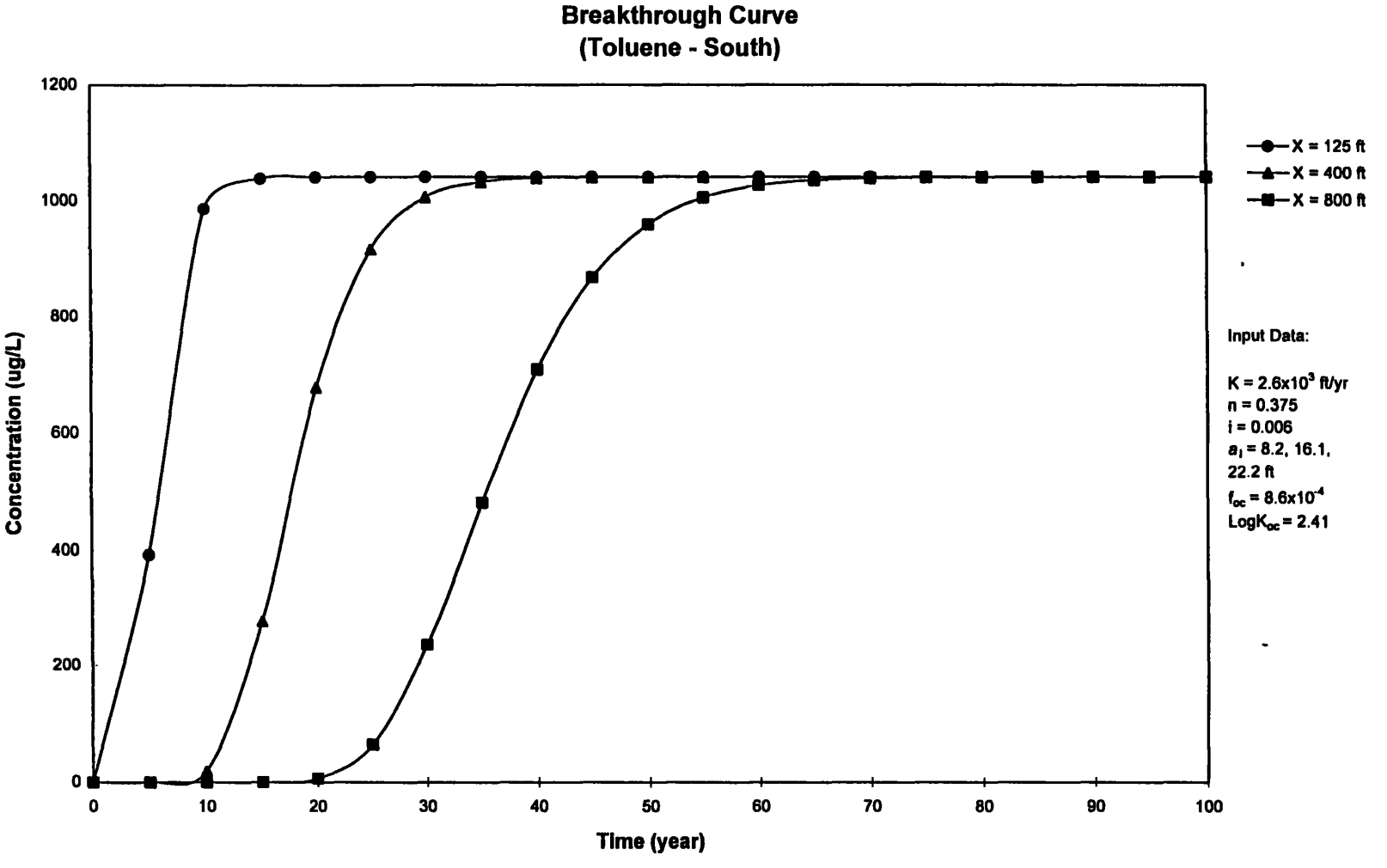
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

TOLUENE

The remedial goal for toluene, as specified in the ROD, is 28 ug/l. The effective solubility for toluene is 1,040 ug/l. The concentration versus time graph of the model output indicates an estimated travel time for the groundwater containing toluene at a concentration equal to the ROD remedial goal to reach the hypothetical exposure endpoint (x=400 ft.) is approximately 10 years.

Toluene was not detected in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an toluene concentration of more than 1,000 ug/l in monitoring well MW-08. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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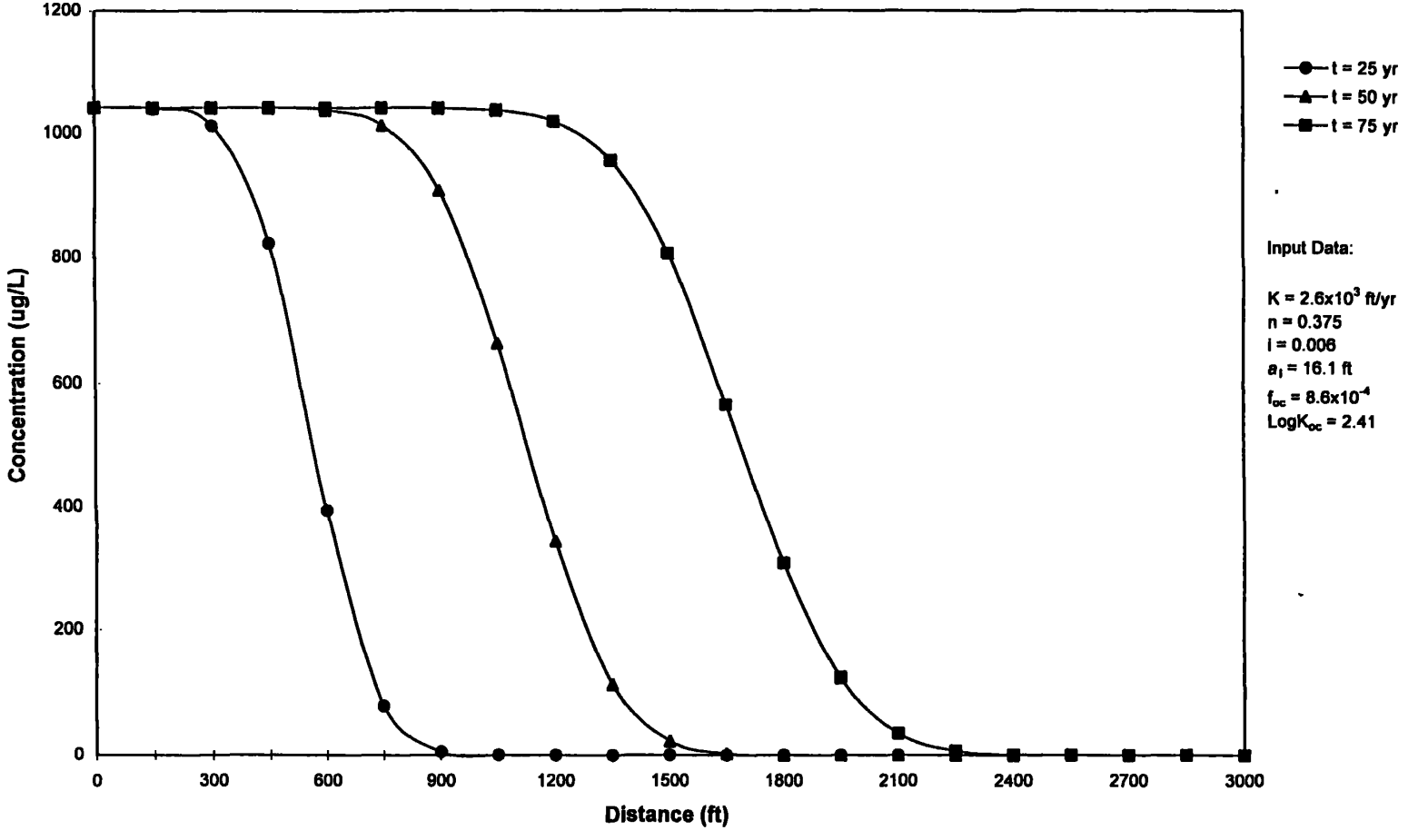
Breakthrough Curve
(Toluene - South)



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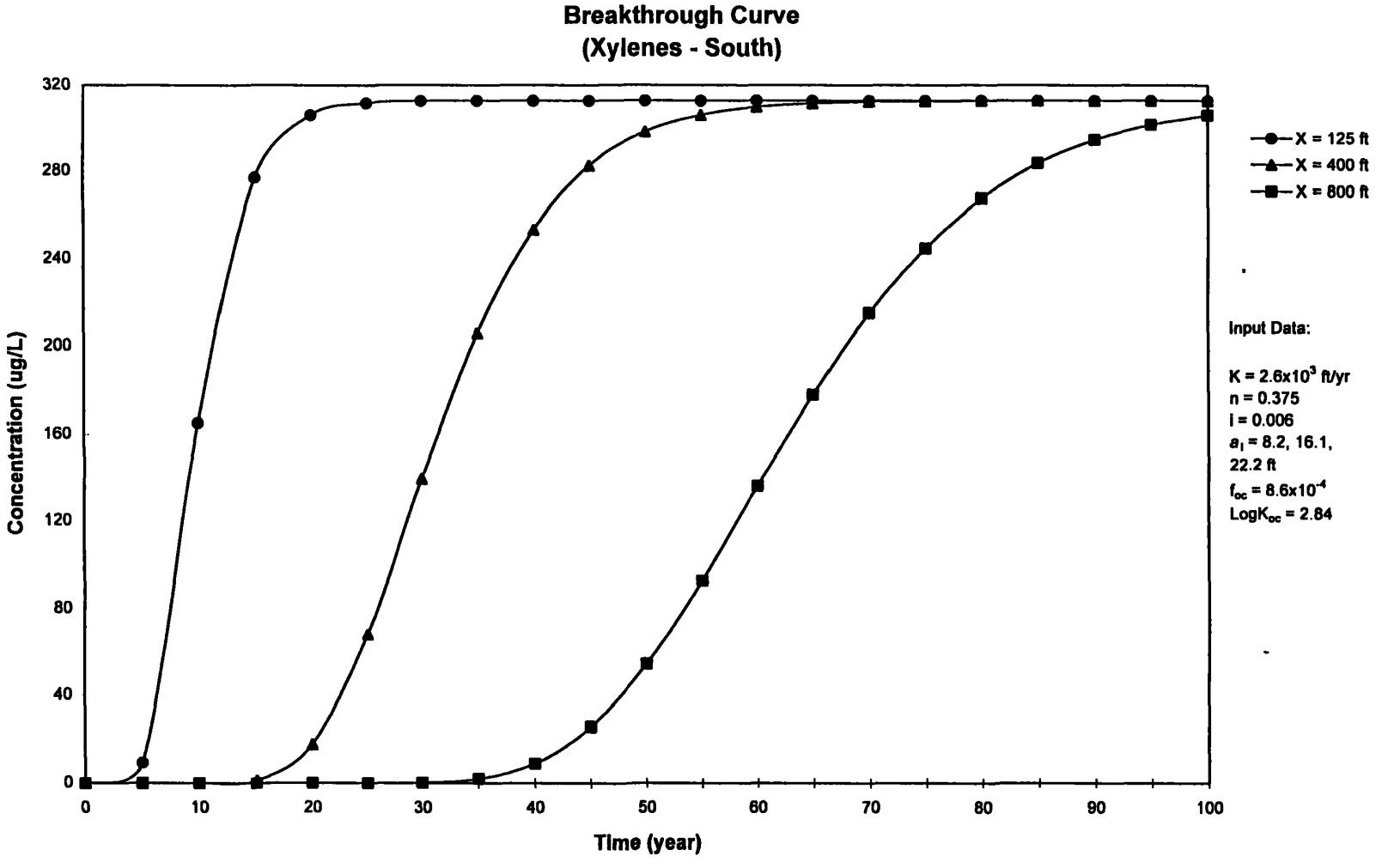
SCENARIO 1A - SOUTHERN AREA
MOST CONSERVATIVE INPUT PARAMETERS (NON-PUMPING CONDITIONS)

XYLENE

The remedial goal for xylene, as specified in the ROD, is 440 ug/l. The effective solubility for toluene (313 ug/l) is slightly less than the ROD goal. The concentration versus time graph of the model output indicates that the estimated travel time for the advective front to reach the hypothetical exposure endpoint (x=400 ft.) is approximately 65 years.

Xylene was not detected in monitoring well MW-08 located at a distance of approximately 350 feet downgradient of the potential source area during the RI groundwater sampling event. Conservatively assuming that the source area did not exist until the last year of plant operation, the model simulation predicts an xylene concentration of more than 240 ug/l in monitoring well MW-08. This comparison of actual and predicted concentrations reflects the conservative nature of this scenario. The significant difference between the actual and simulated concentrations may be due to overly conservative values for the input parameters and/or the fact that this simulation does not account for the effects of biodegradation.

This parameter will be evaluated further under the less conservative scenarios.



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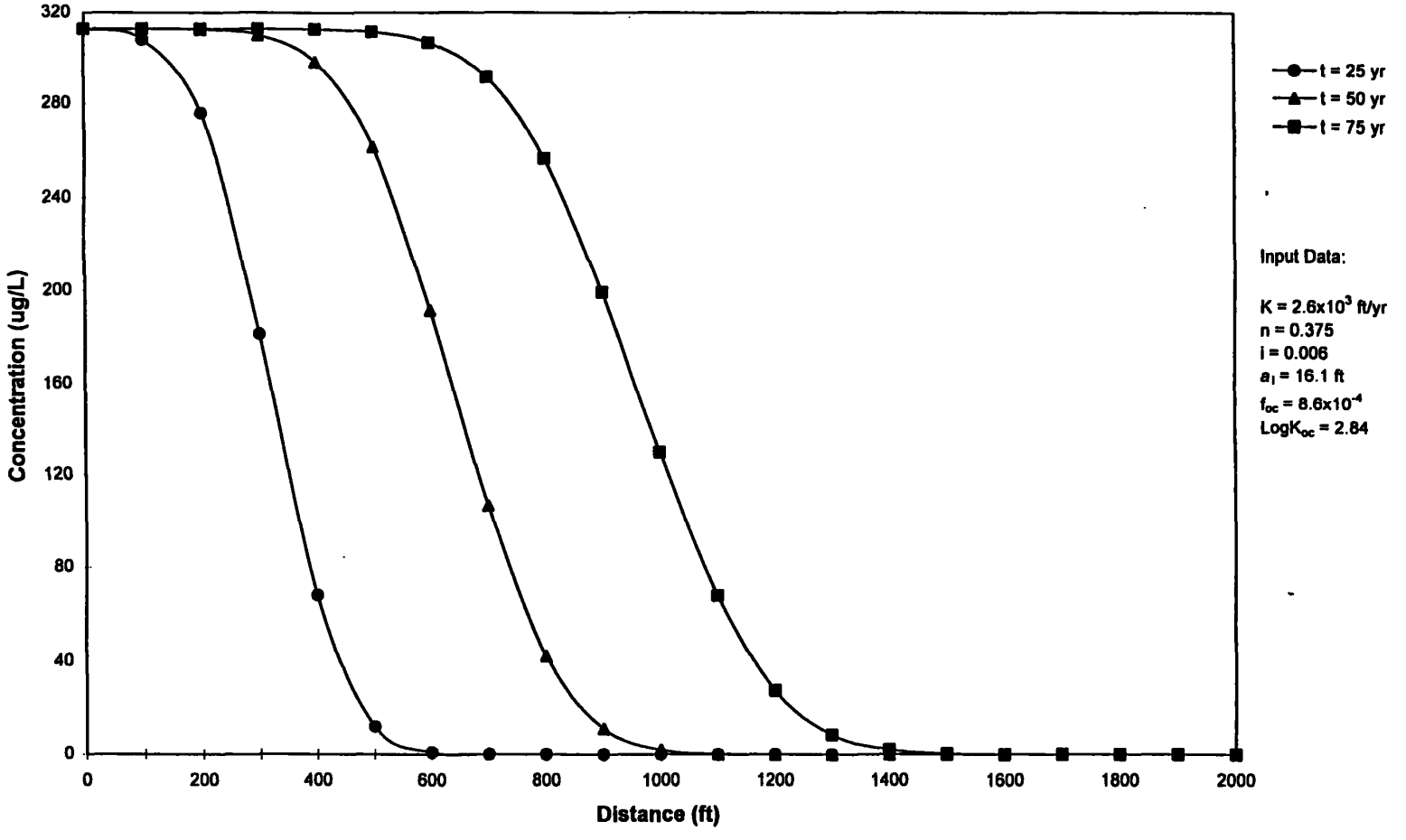
Breakthrough Curve
(Xylenes - South)



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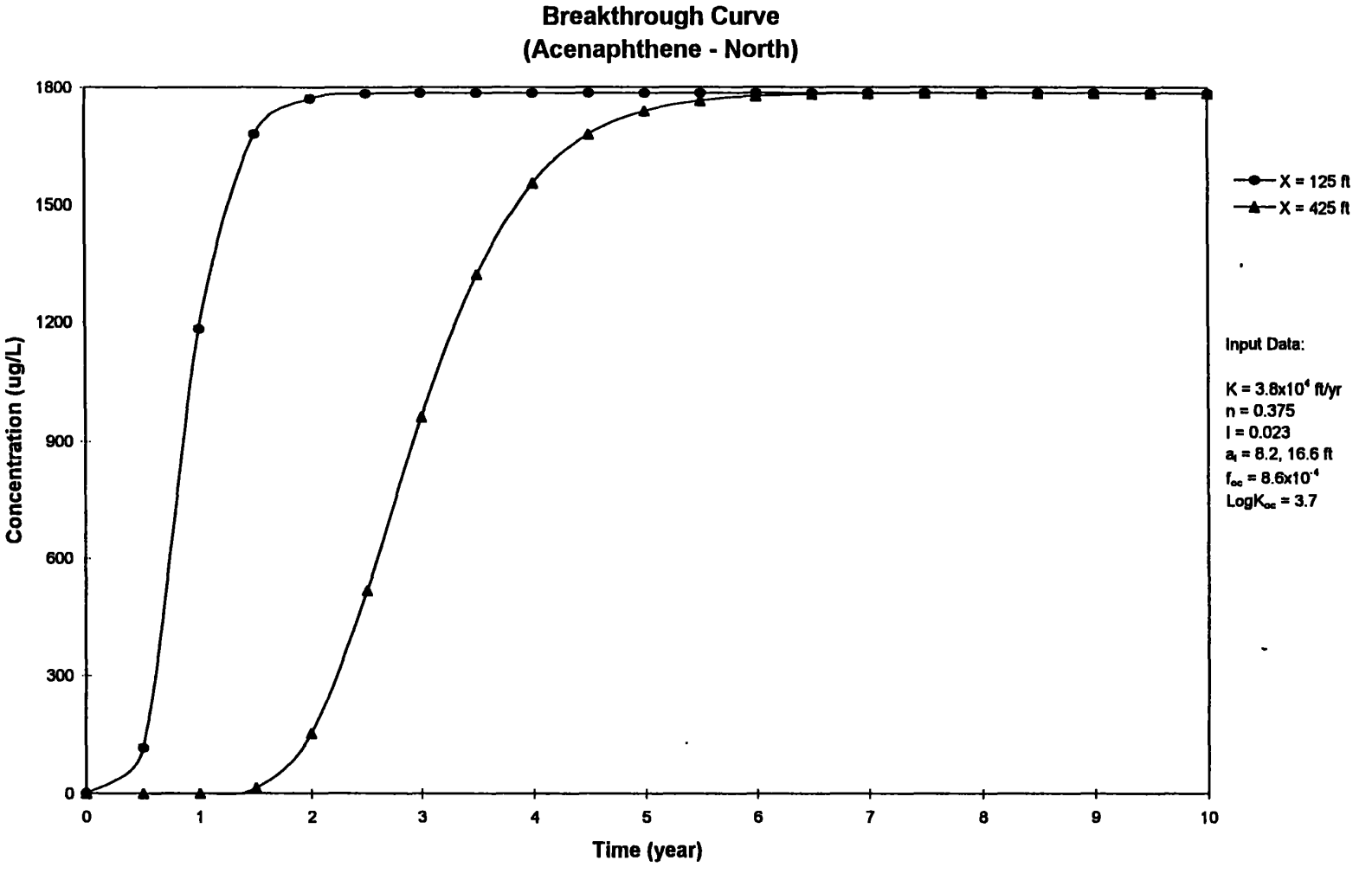
APPENDIX D

SCENARIO 1B - WORST CASE SIMULATION FOR PUMPING CONDITIONS

KEY ENVIRONMENTAL INCORPORATED



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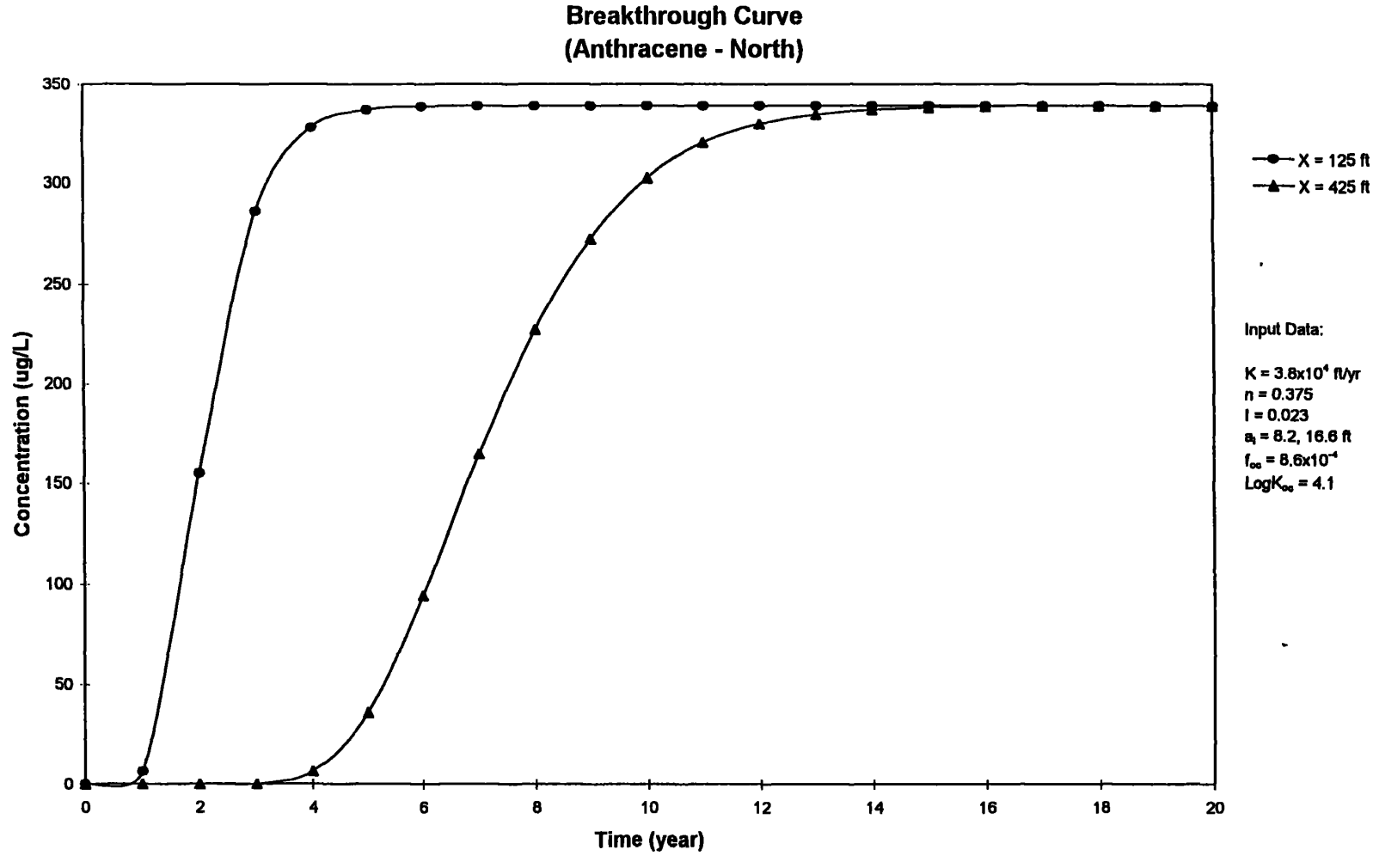

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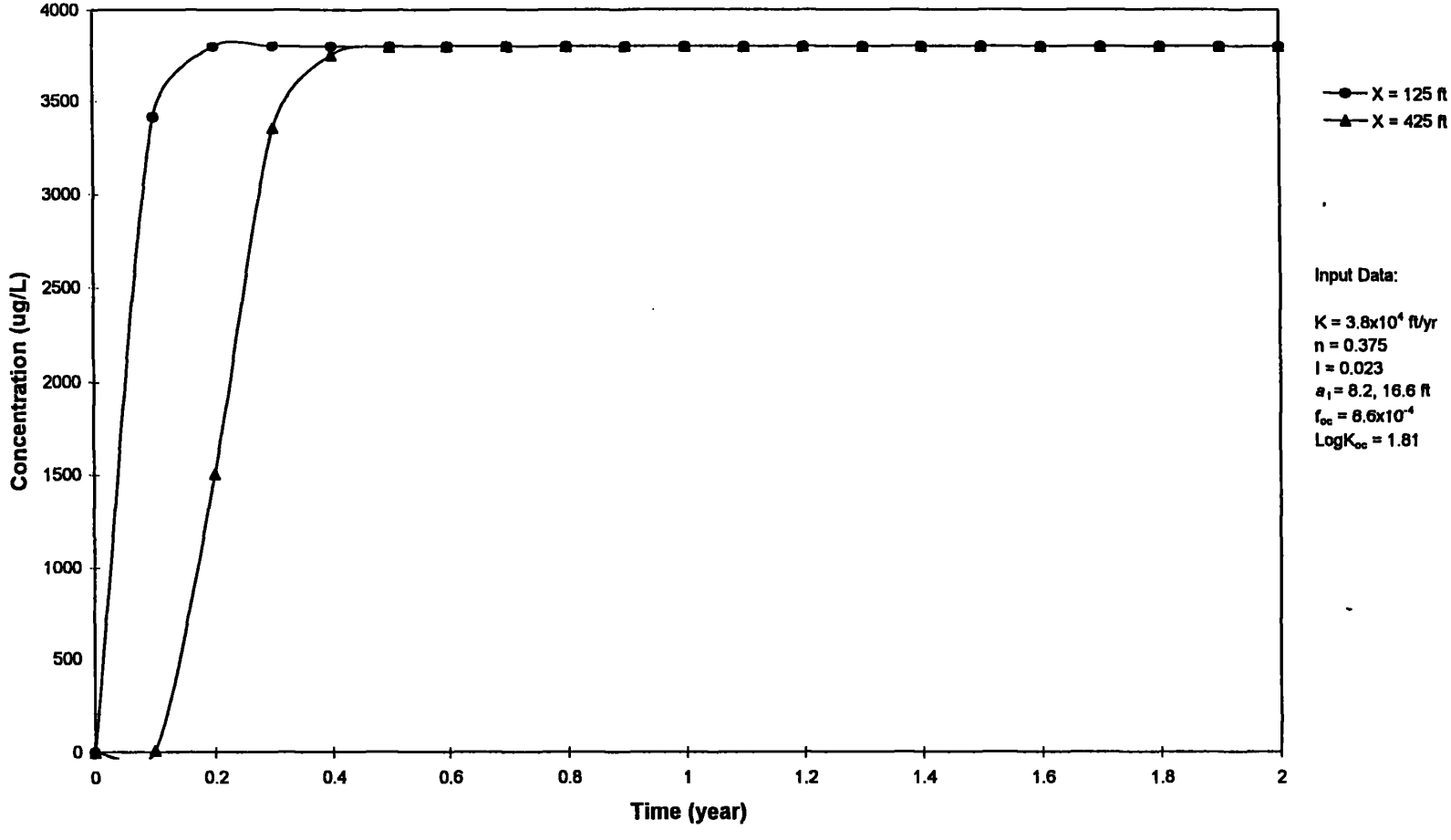
Breakthrough Curve
(Benzene - North)

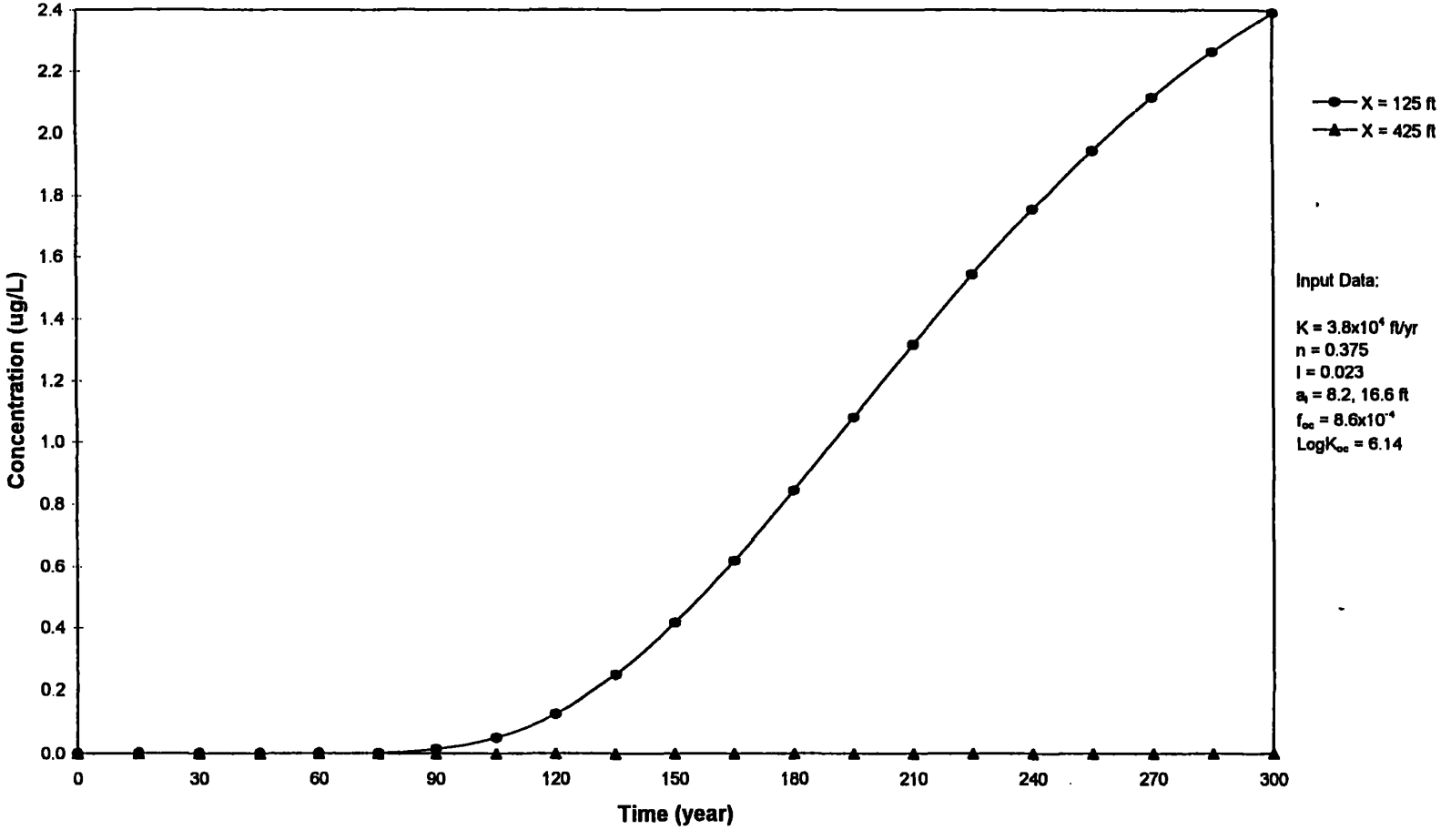


Input Data:

K = 3.8×10^{4} ft/yr
n = 0.375
I = 0.023
a_l = 8.2, 16.6 ft
f_{oc} = 8.6×10^{-4}
LogK_{oc} = 1.81

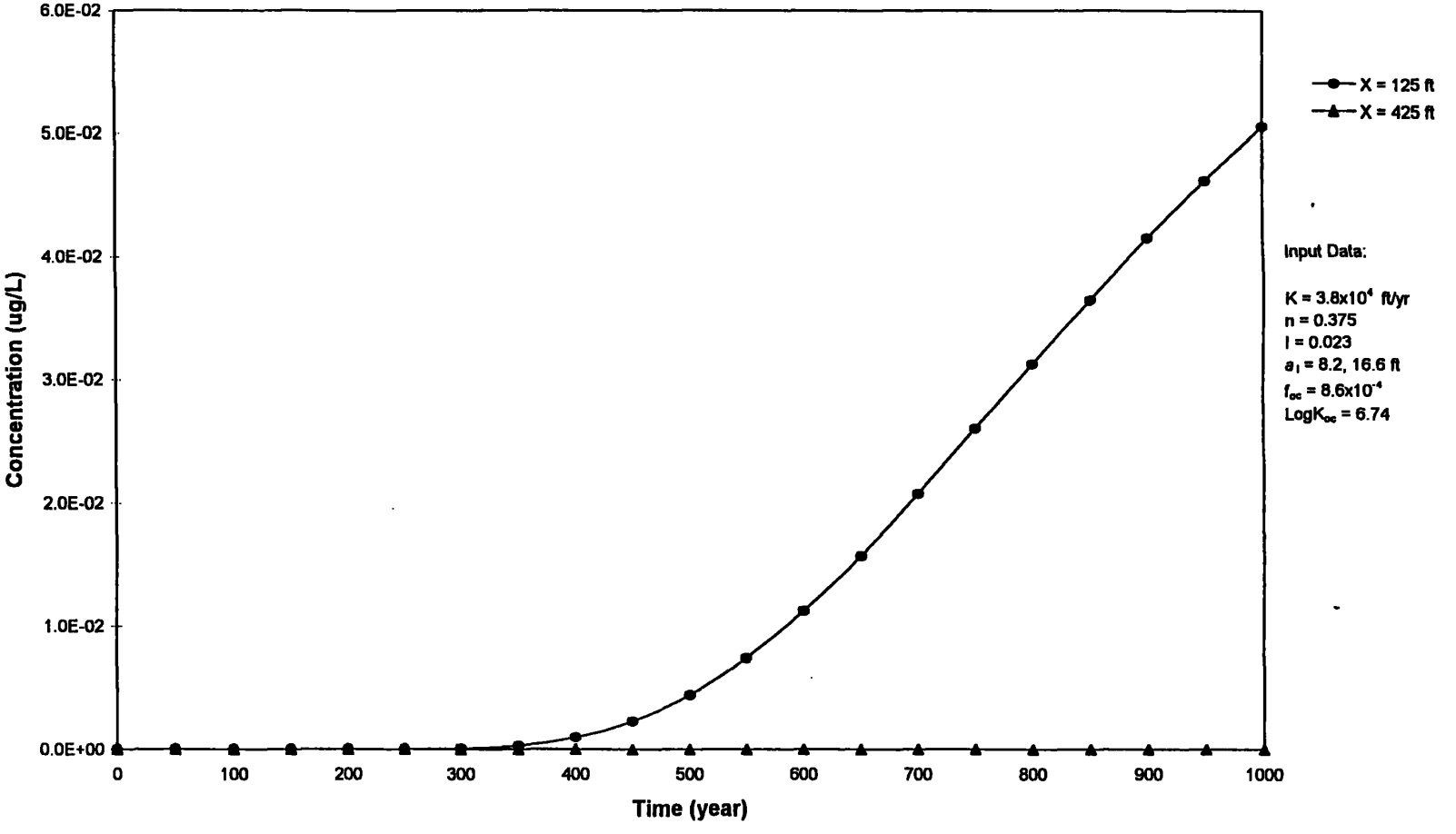
c:\jrh\socav\118-03n.xls

Breakthrough Curve
(Benzo(a)anthracene - North)



c:\jrh\socav\118-04n.xls

Breakthrough Curve
(Benzo(a)pyrene - North)



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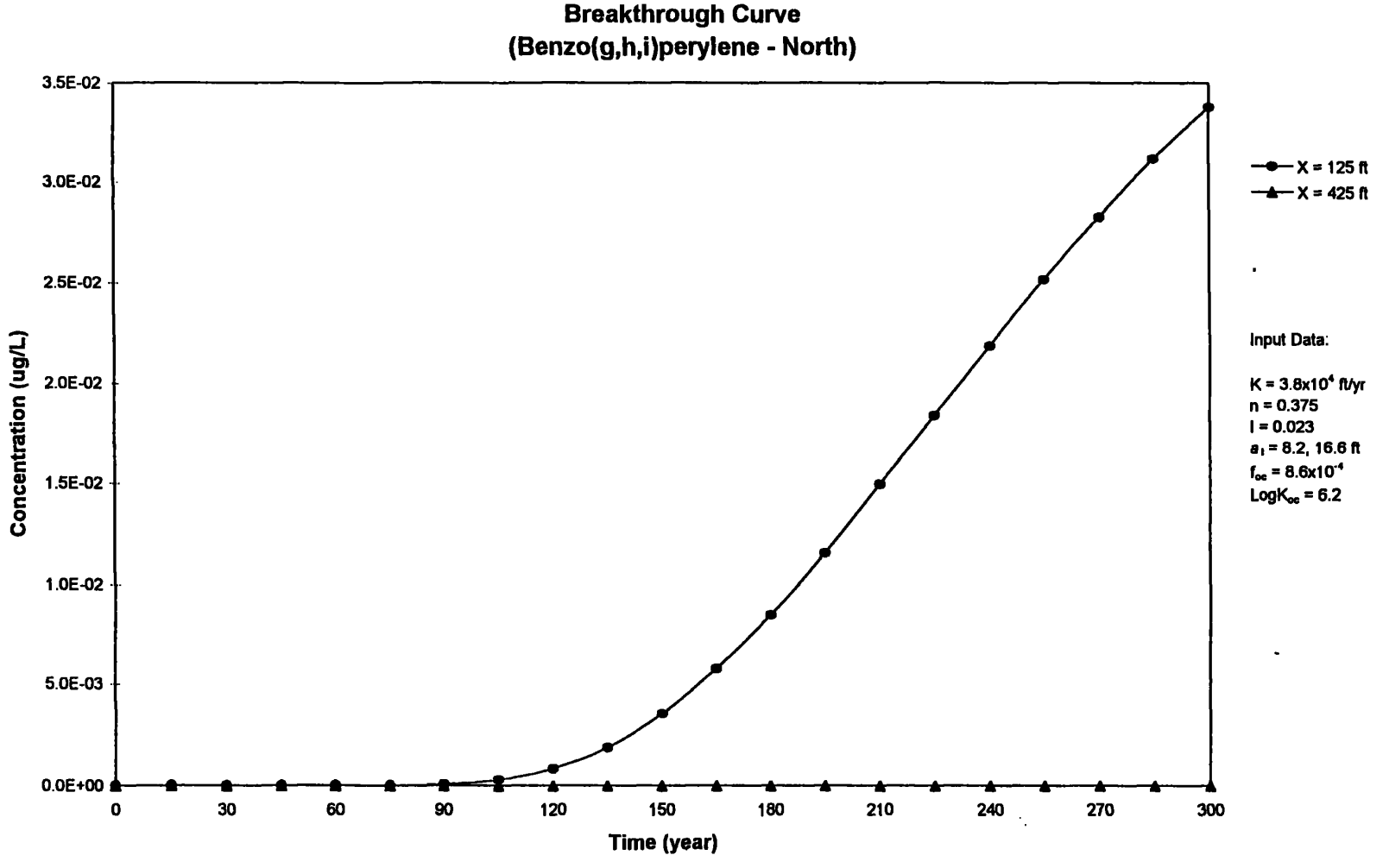

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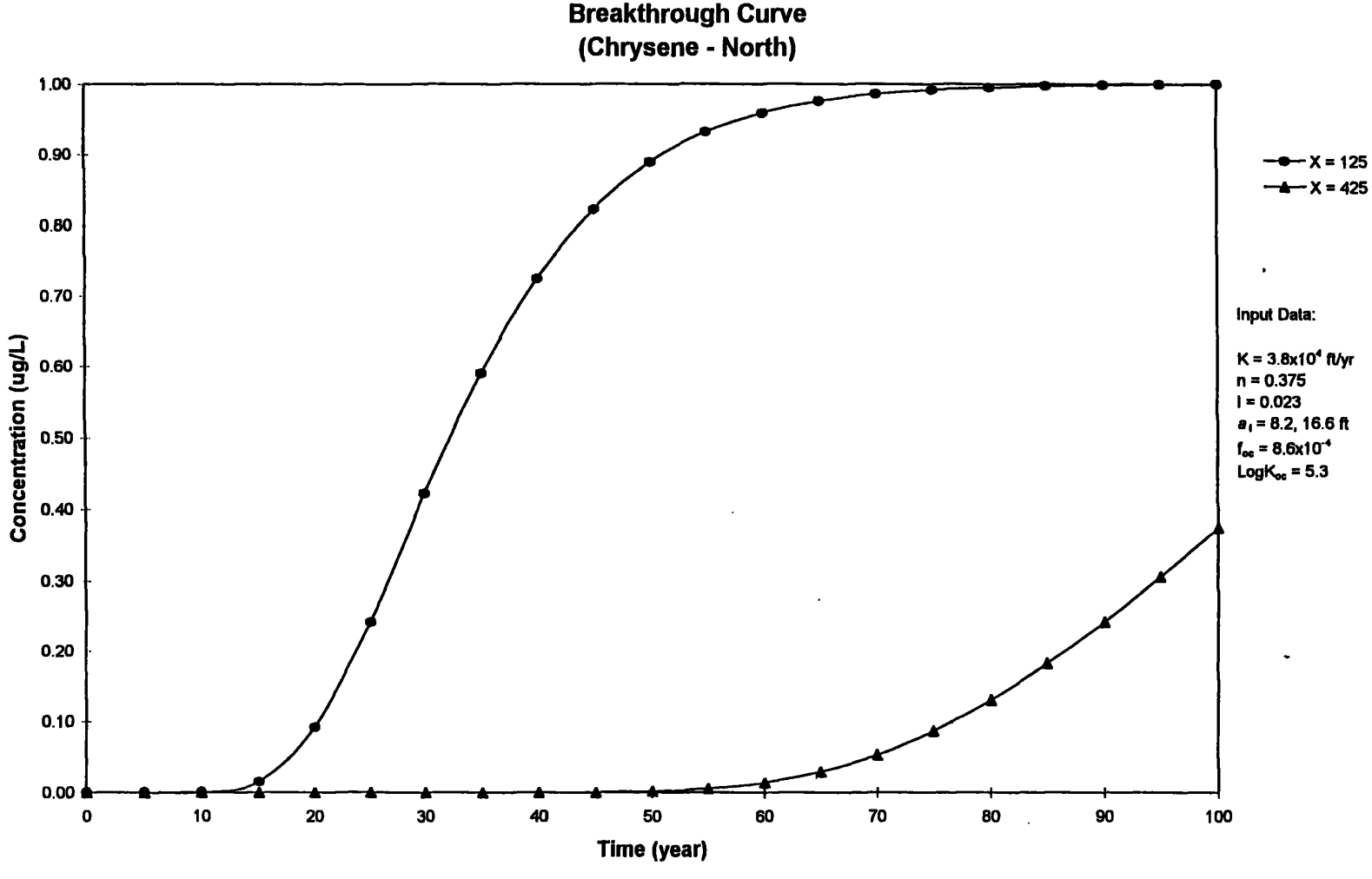

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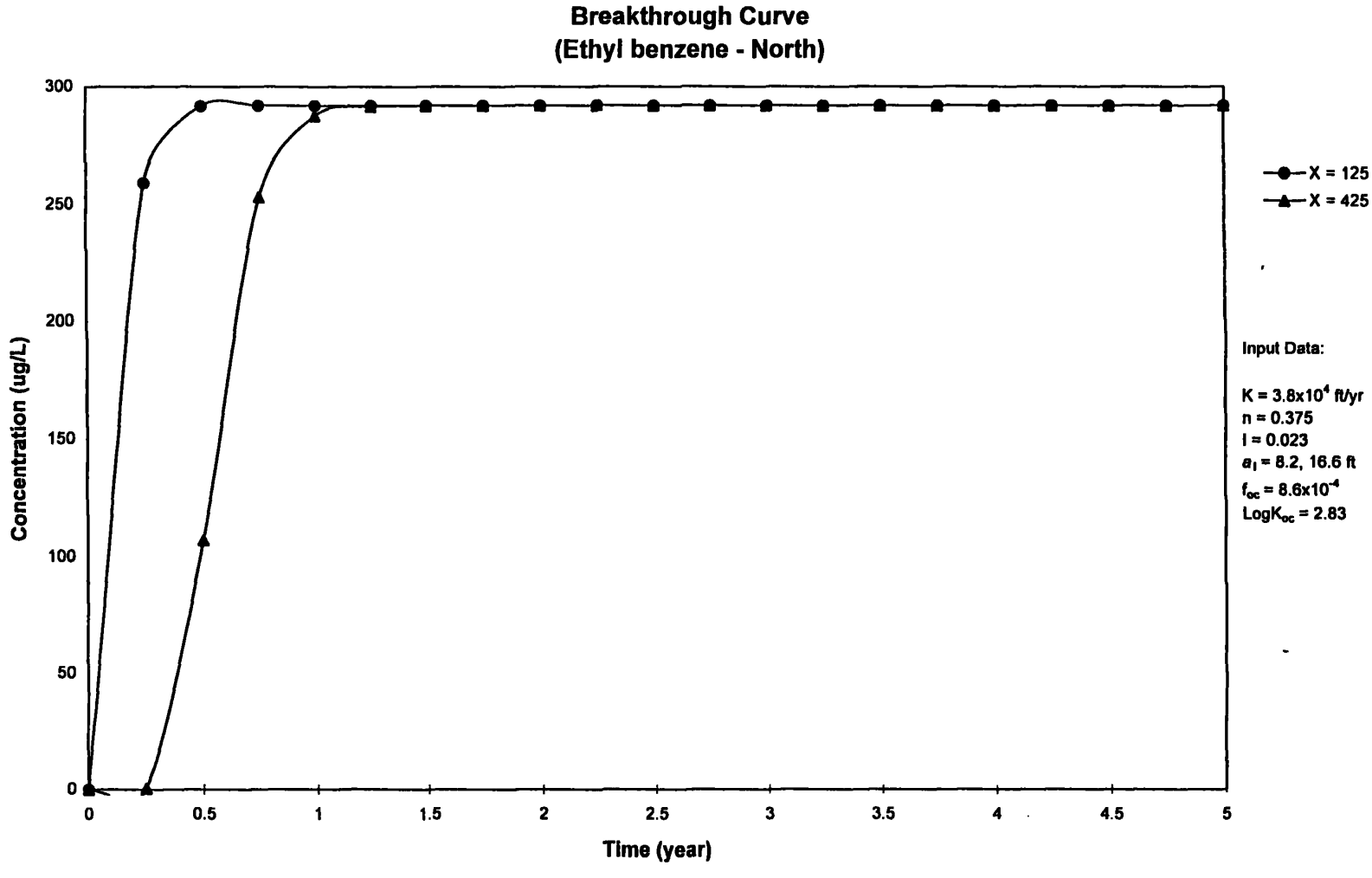
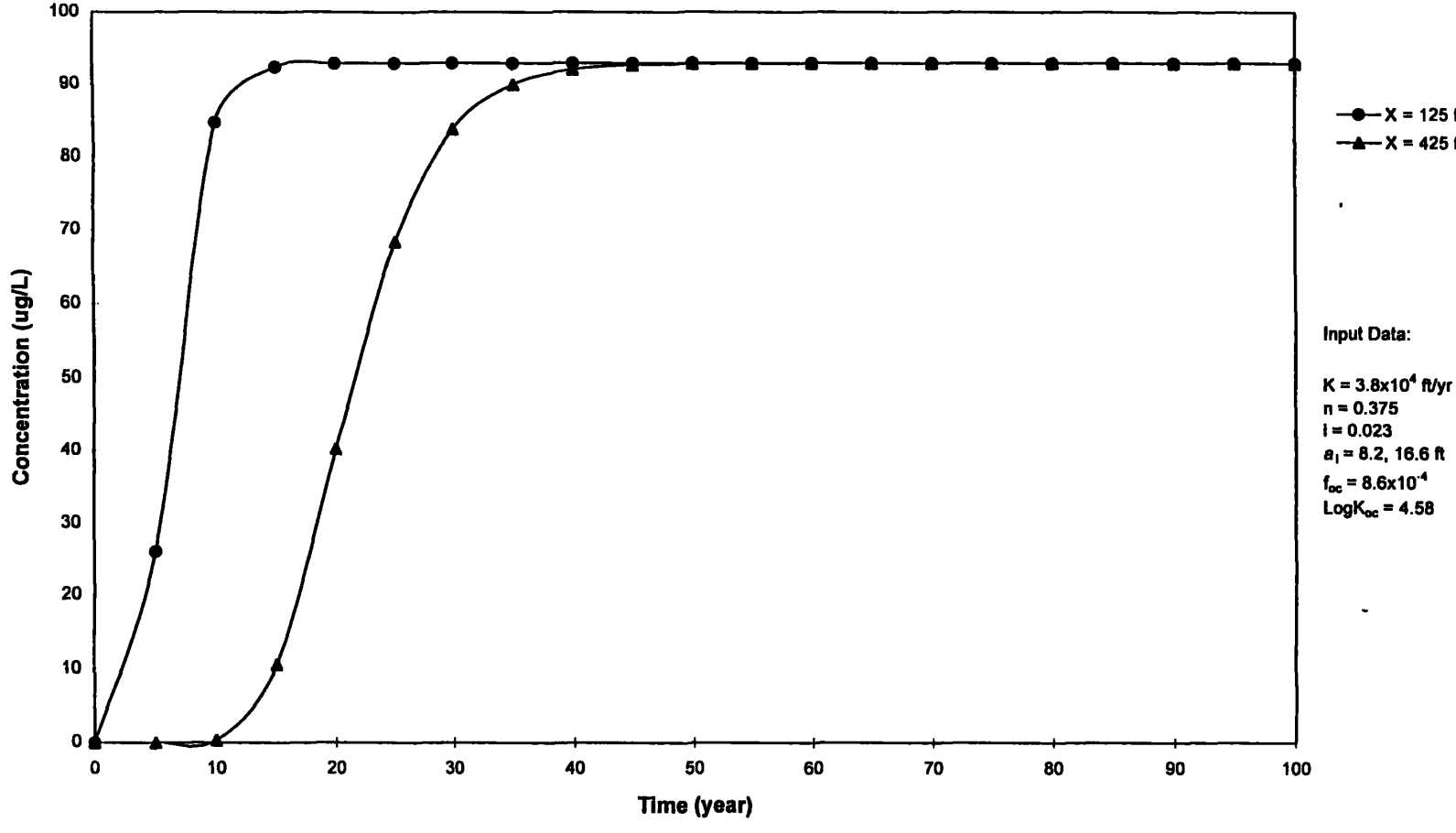
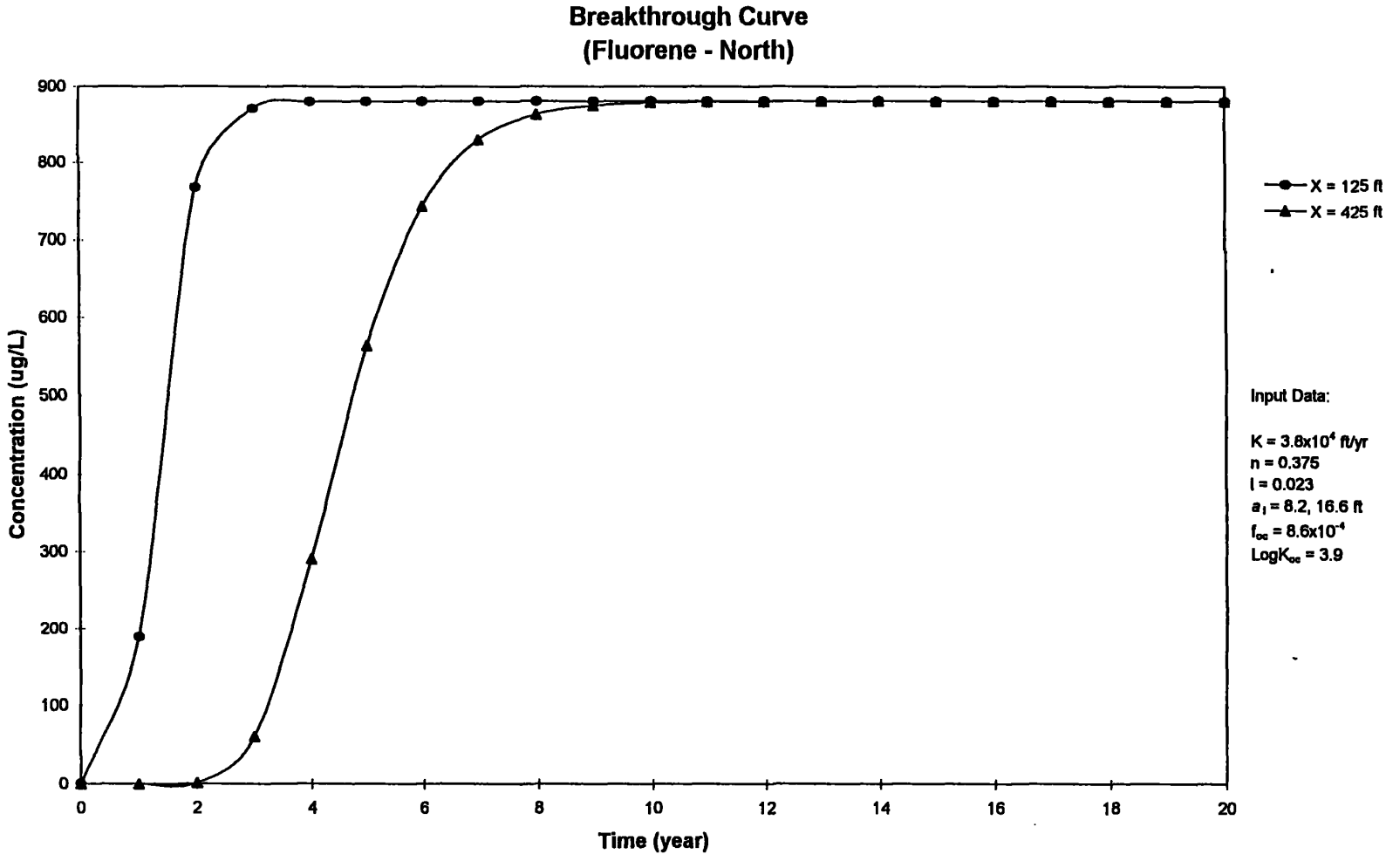


c:\jrh\socav\118-08n.xls

Breakthrough Curve
(Fluoranthene - North)

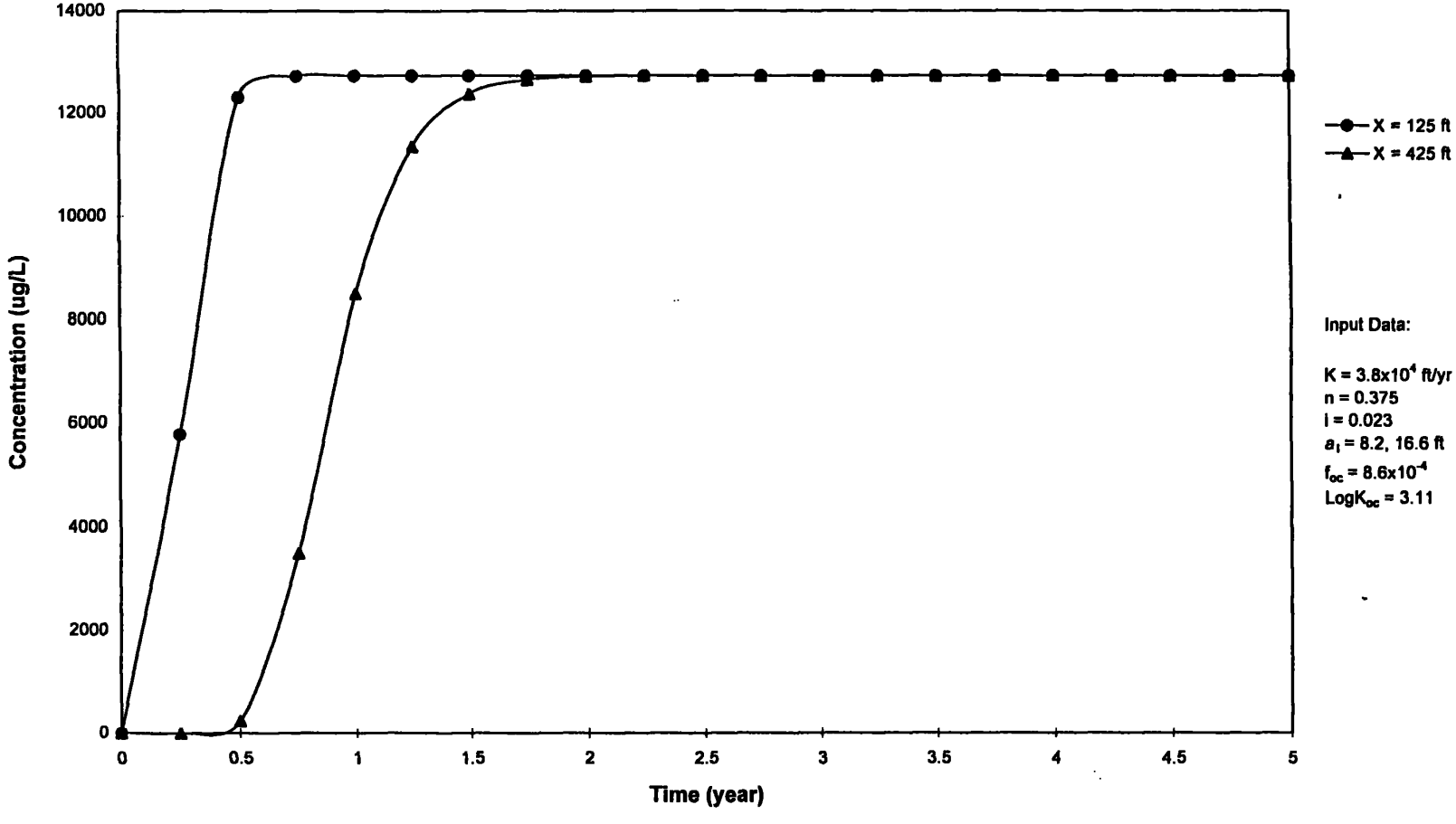


c:\jrh\socav\118-09n.xls



c:\jrh\socav\118-10n.xls

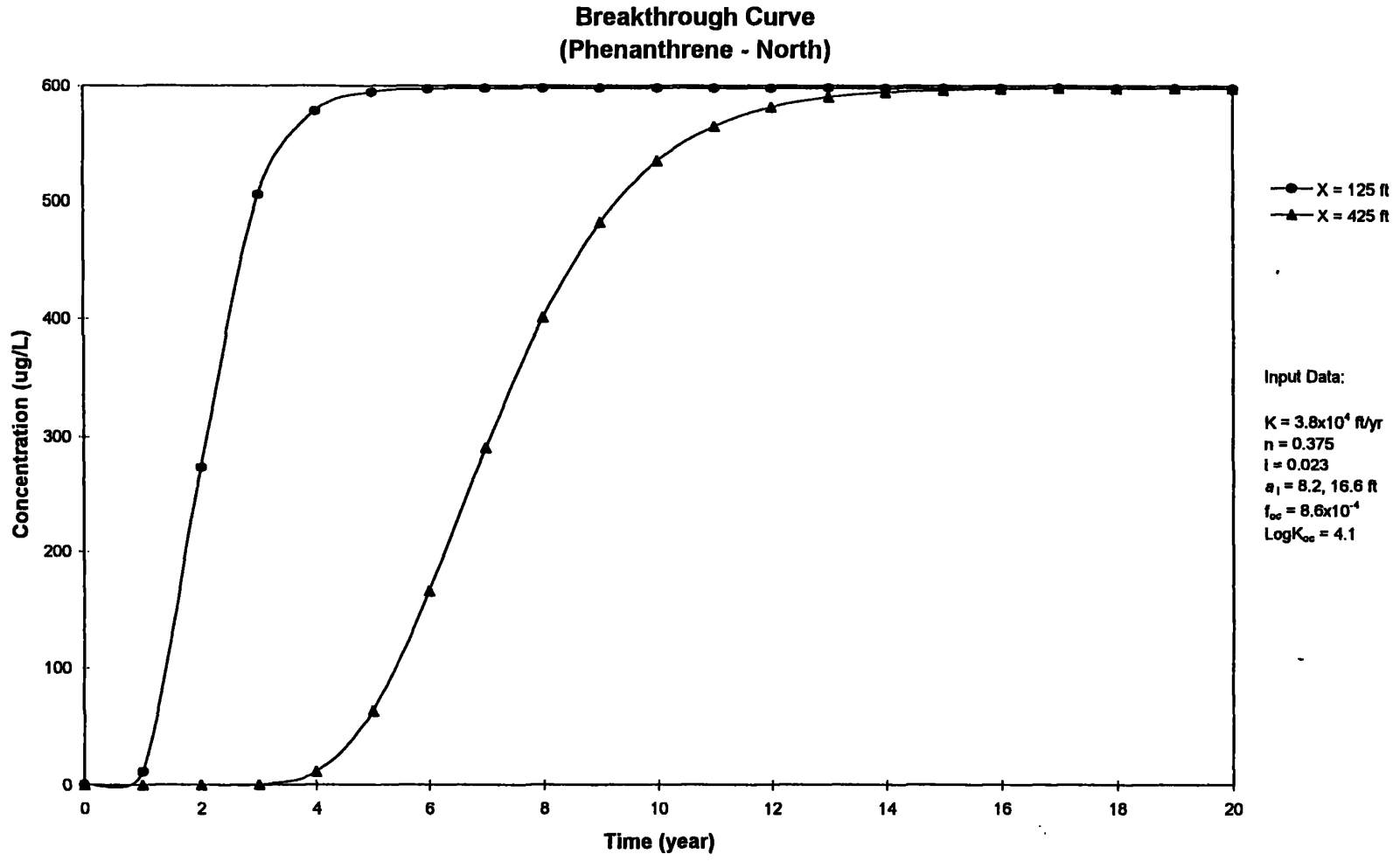
Breakthrough Curve
(Naphthalene - North)



Input Data:

K = 3.8×10^{4} ft/yr
n = 0.375
I = 0.023
a_l = 8.2, 16.6 ft
f_{oc} = 8.6×10^{-4}
LogK_{oc} = 3.11

c:\jrh\socav\118-11n.xls



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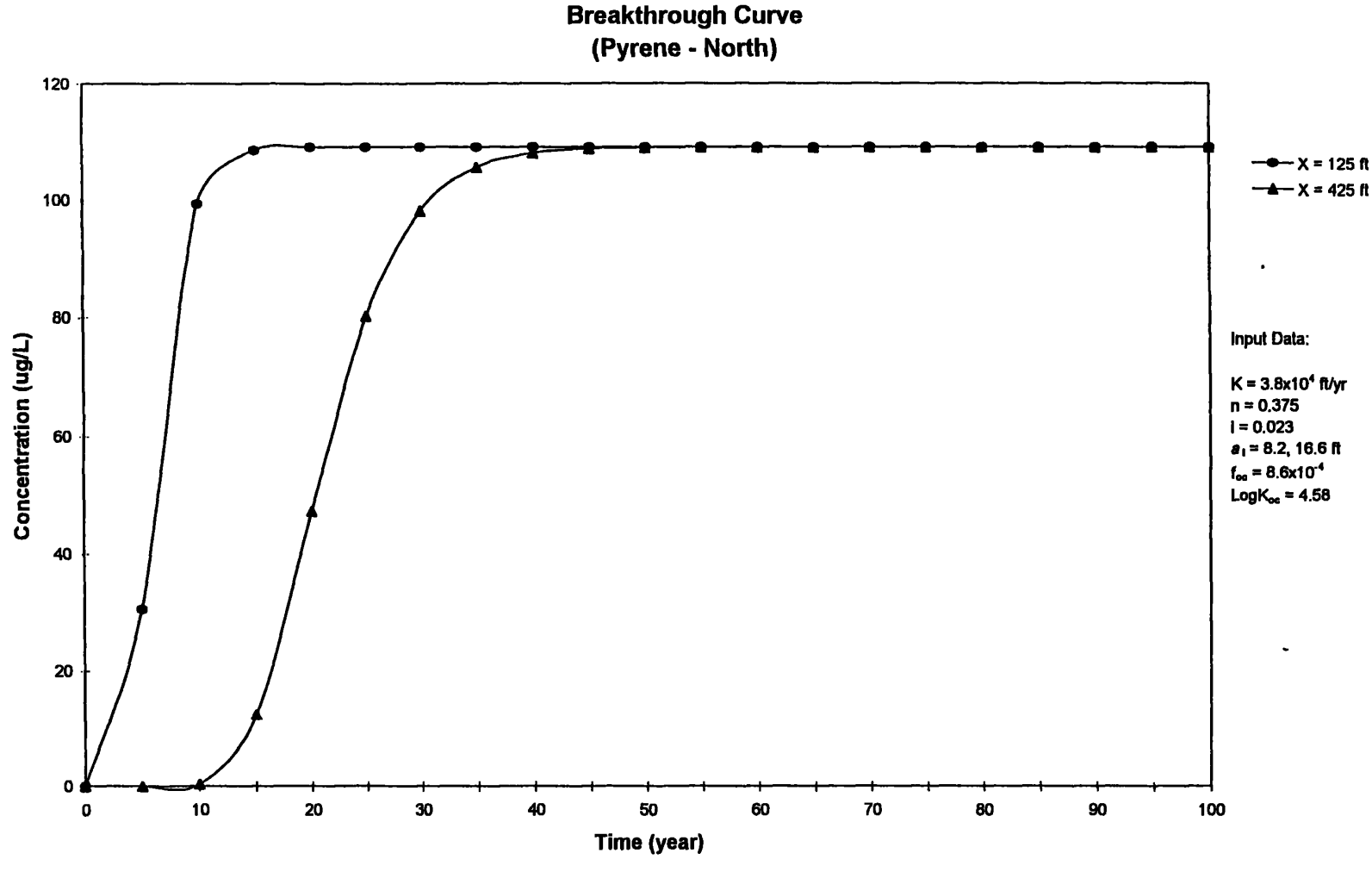
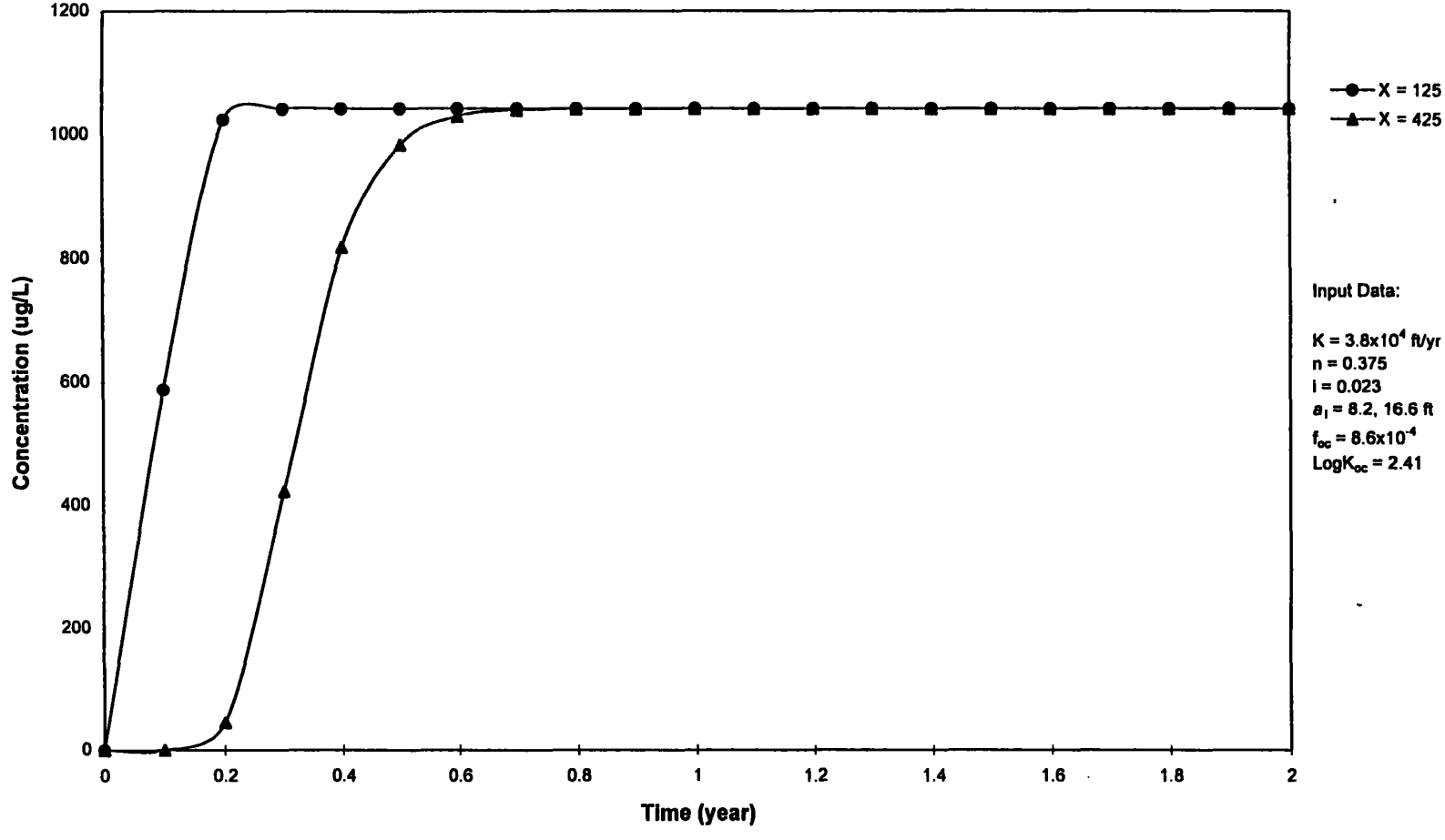


c:\jrh\socav\118-13n.xls

Breakthrough Curve
(Toluene - North)



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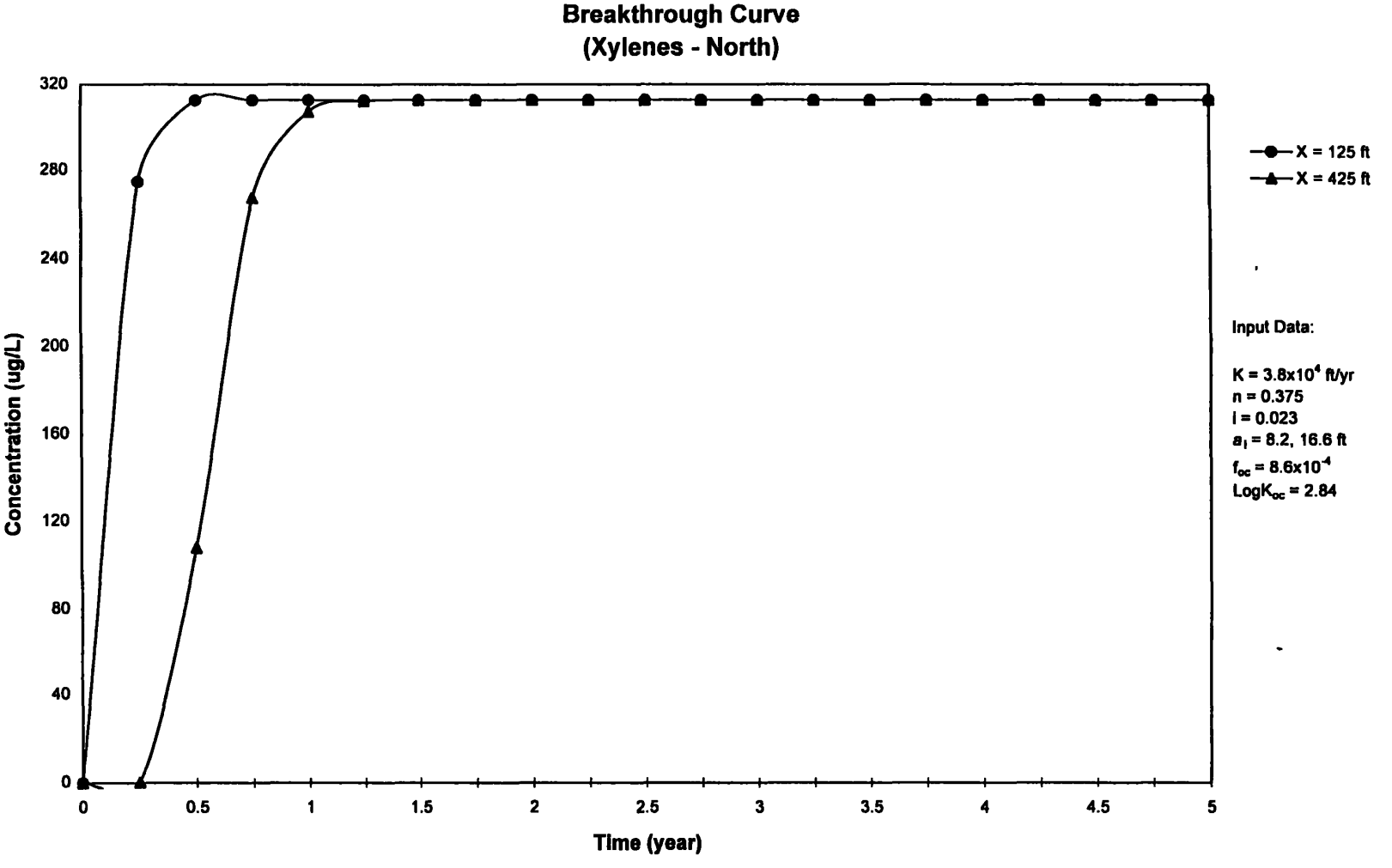

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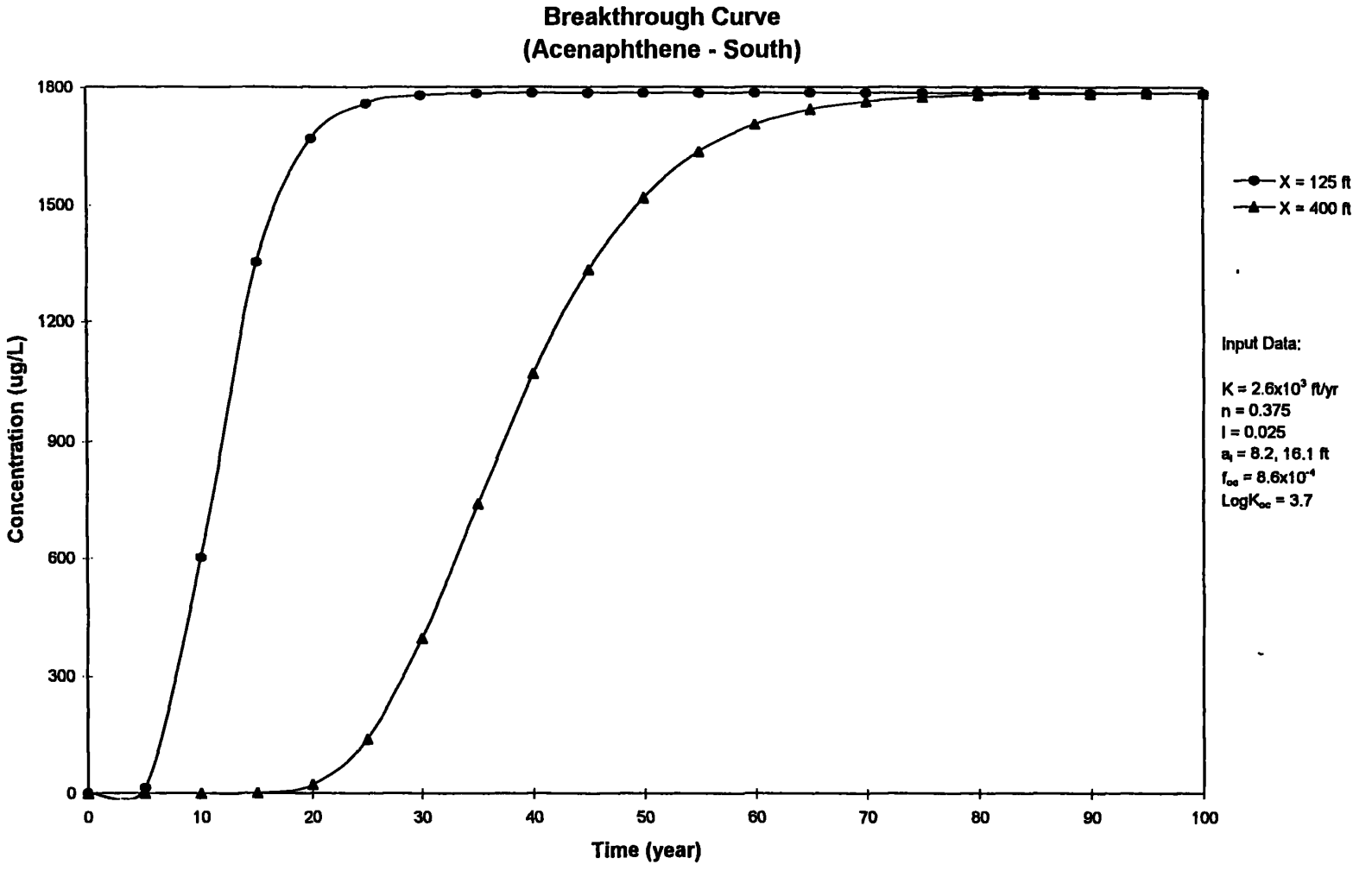

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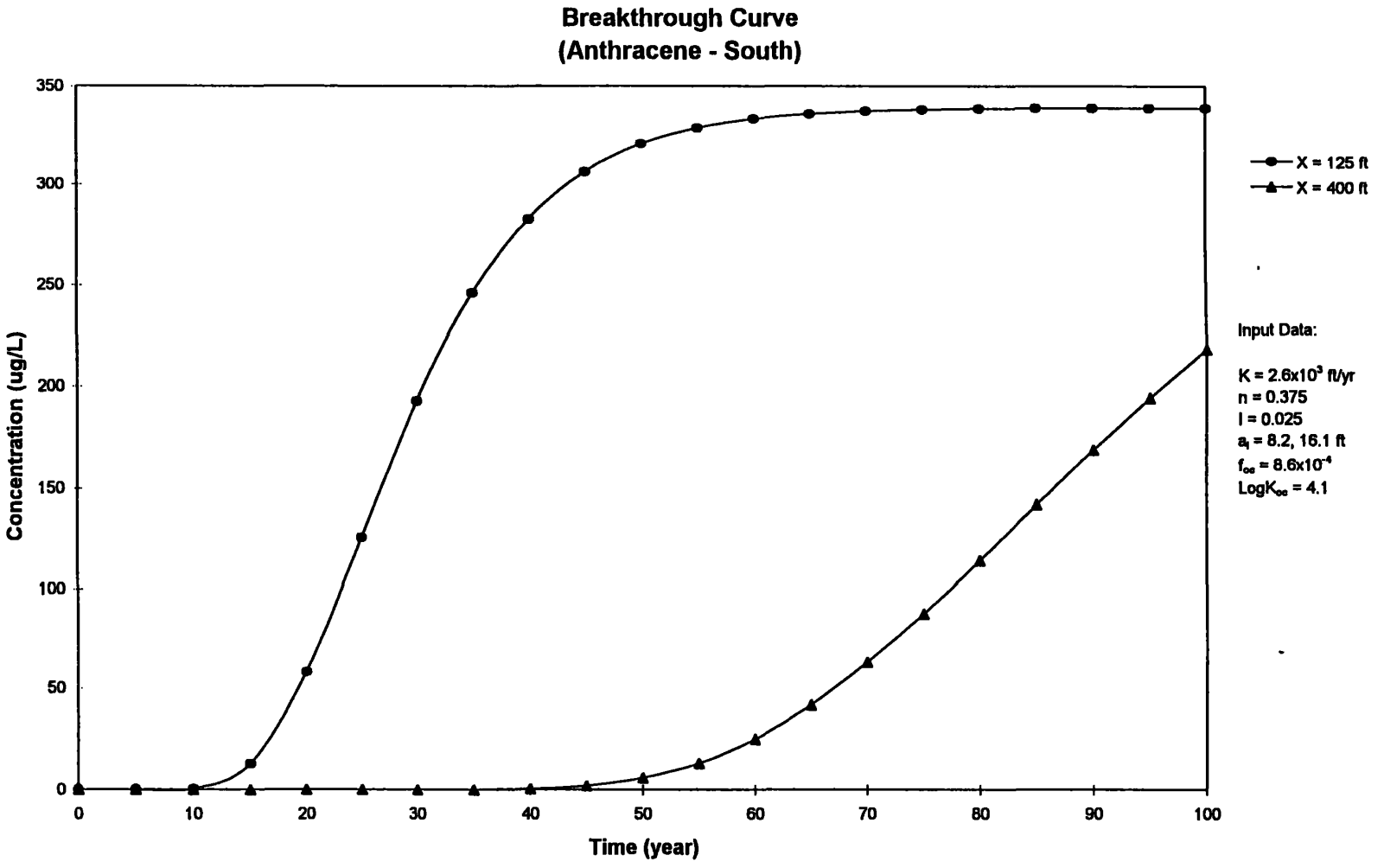

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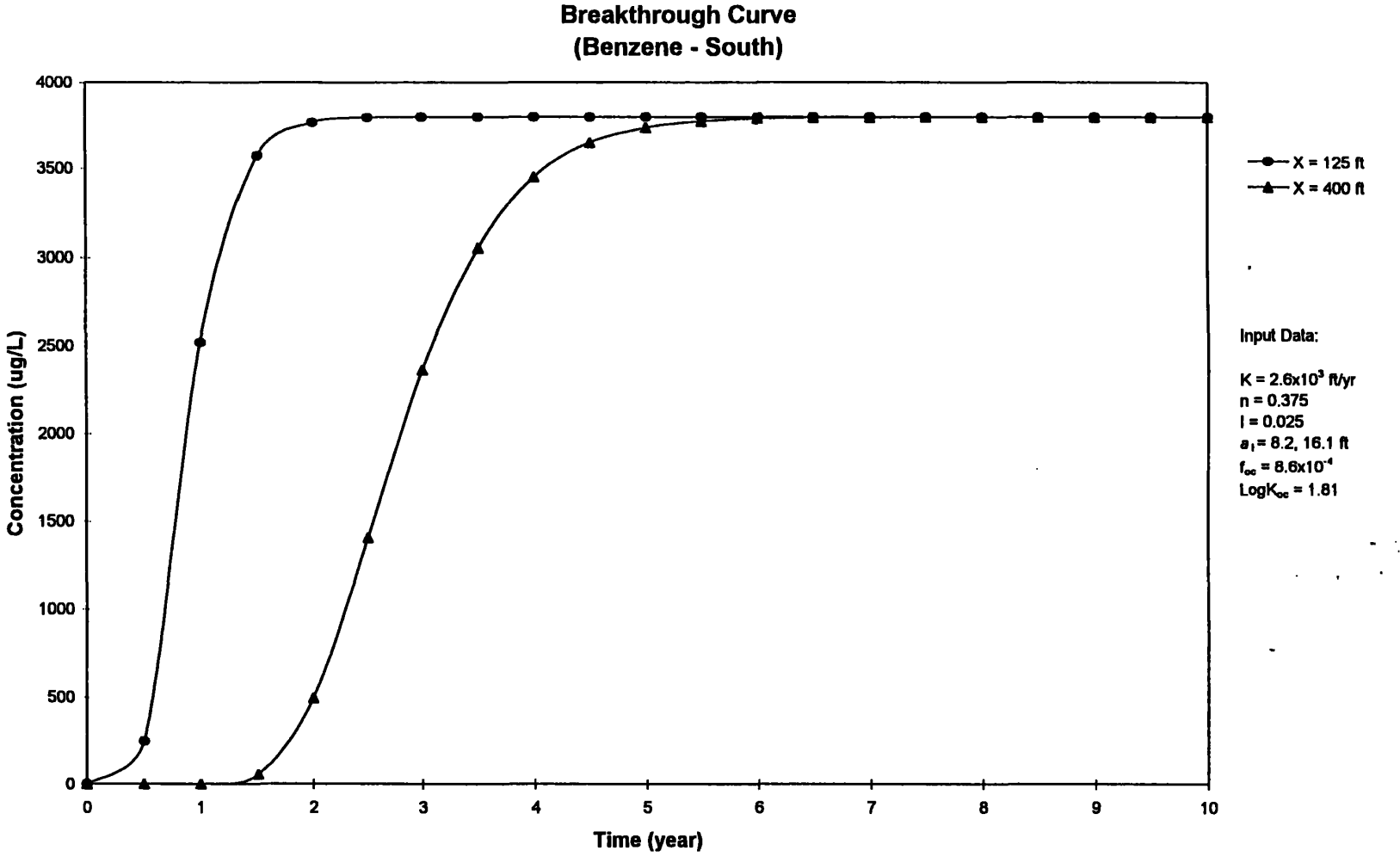

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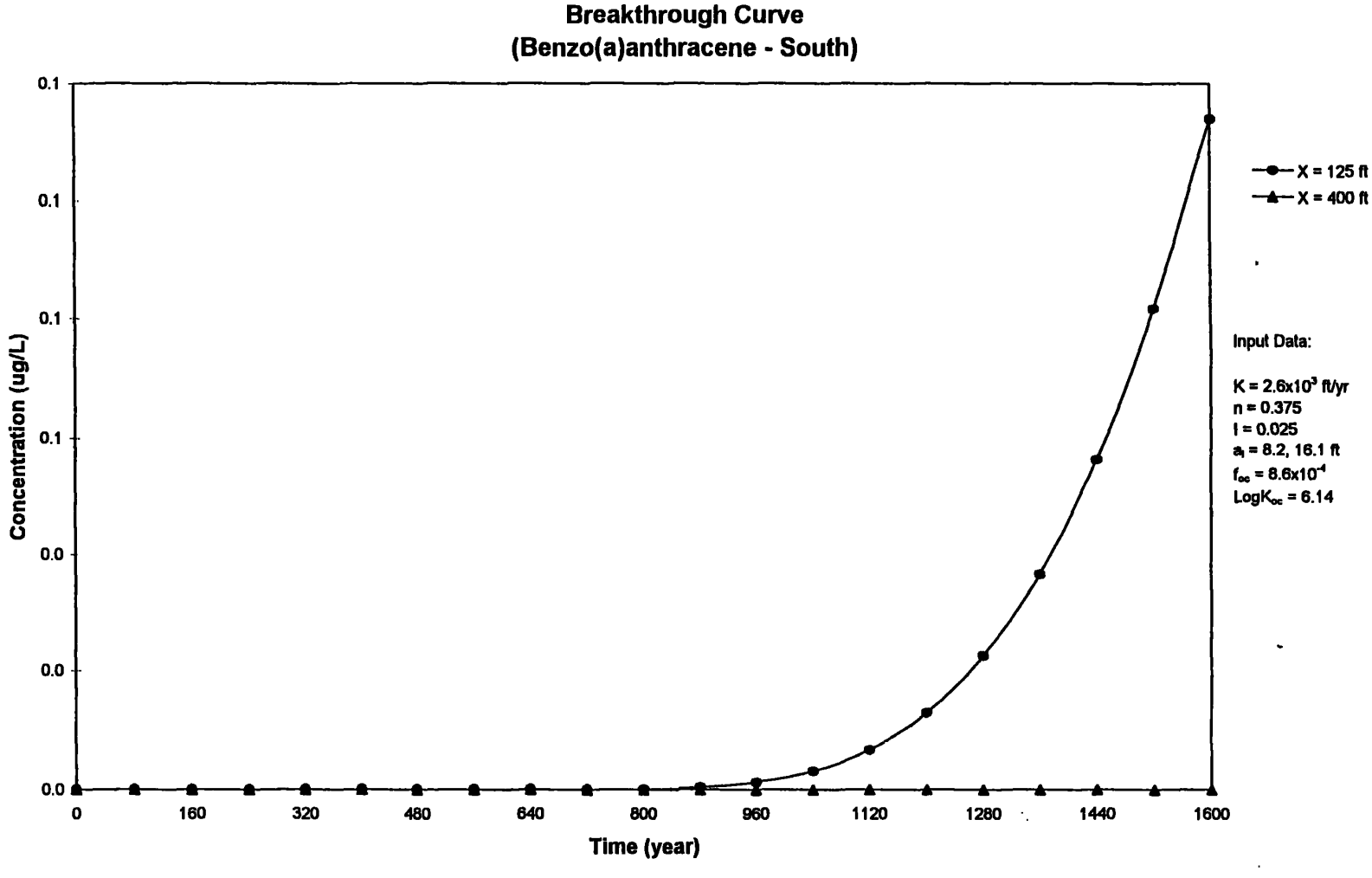

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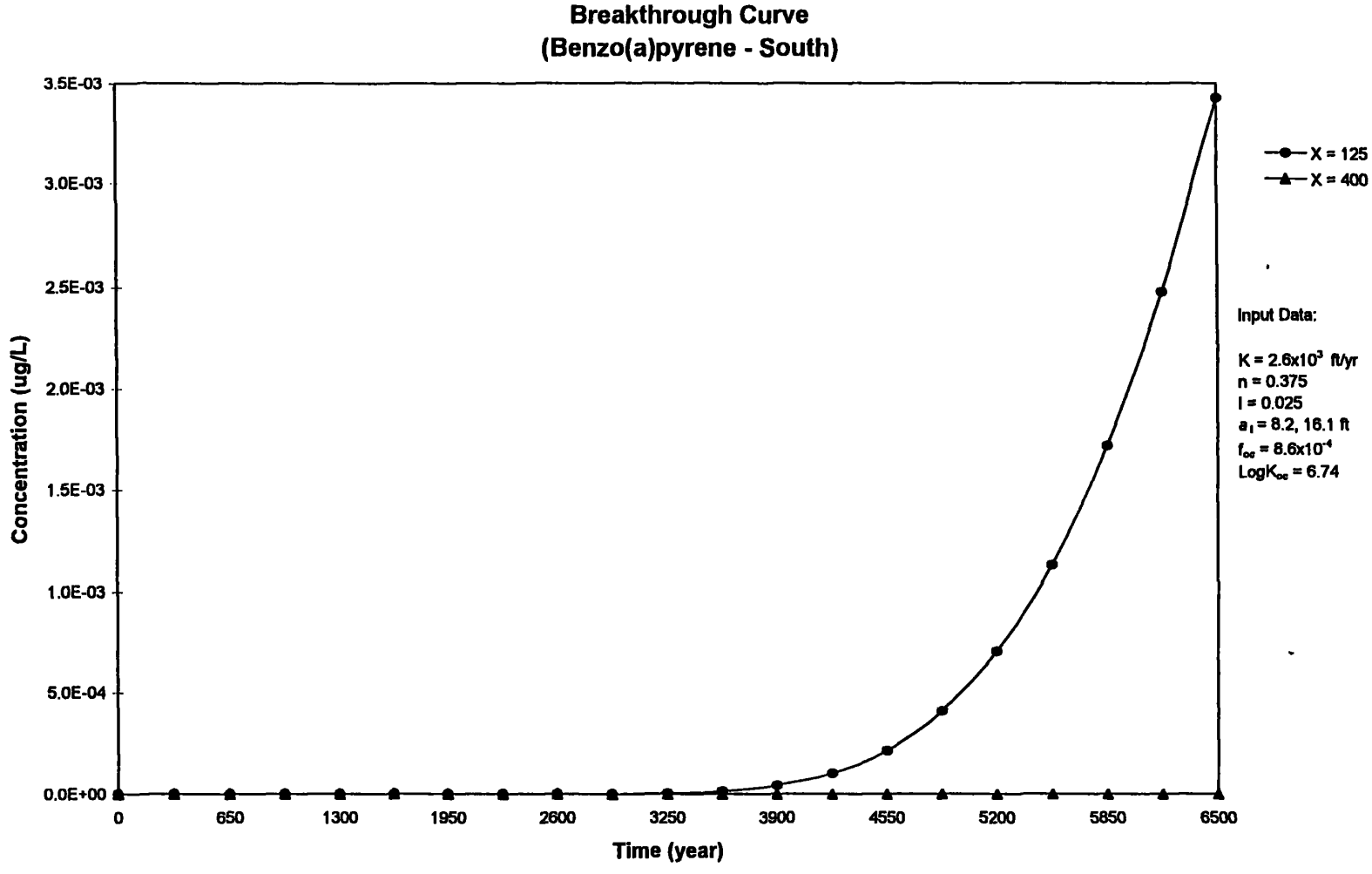

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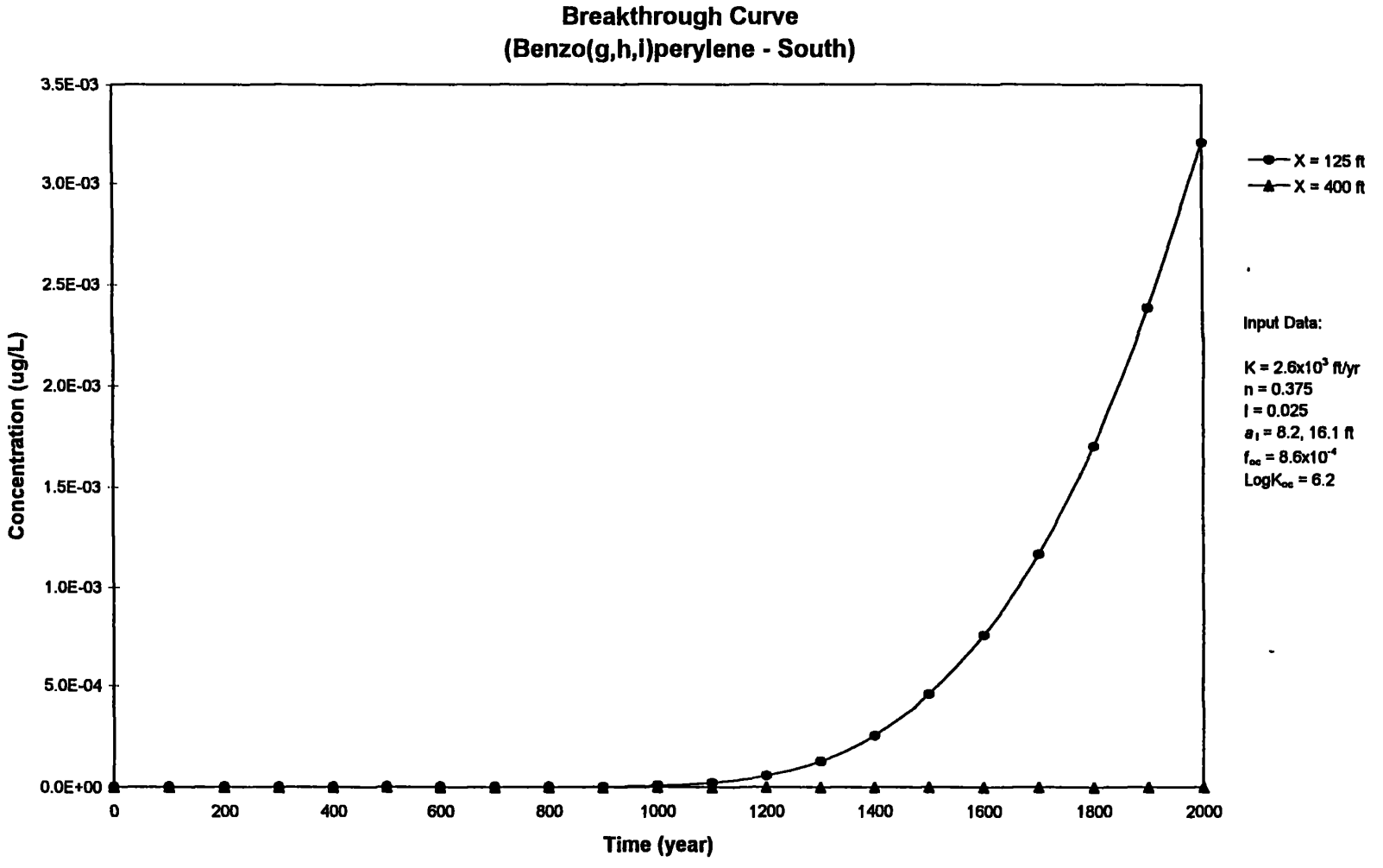

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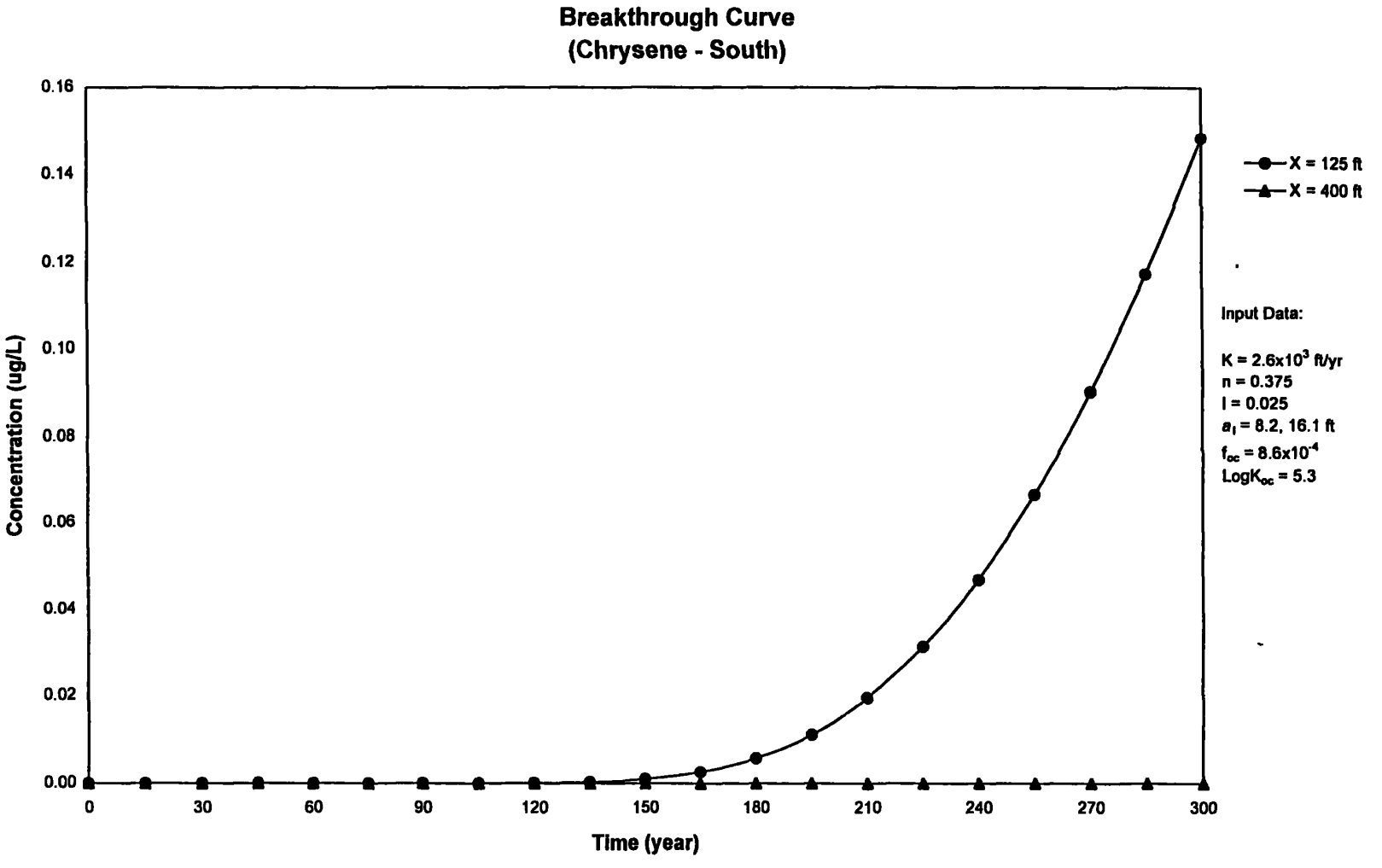

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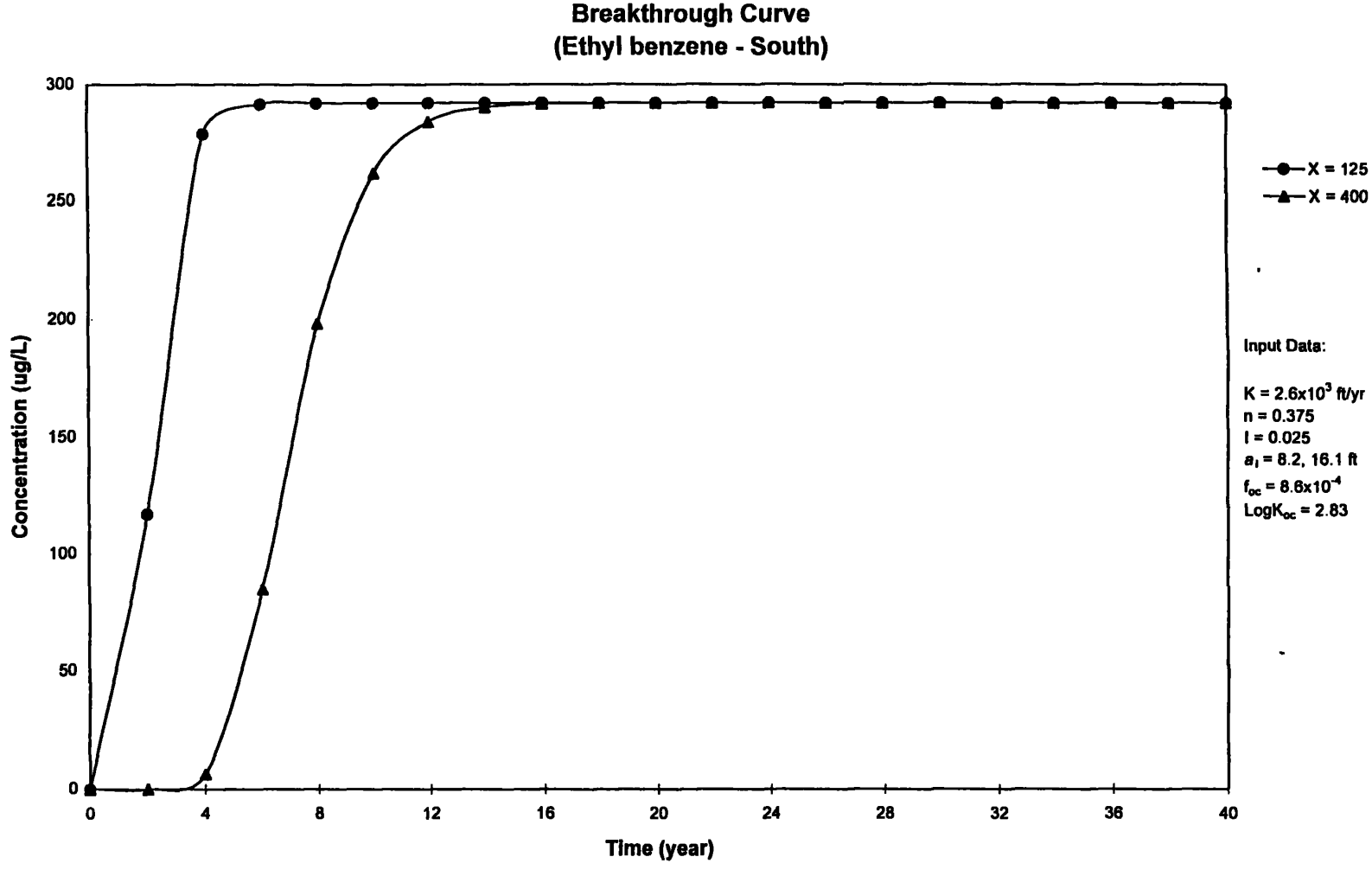

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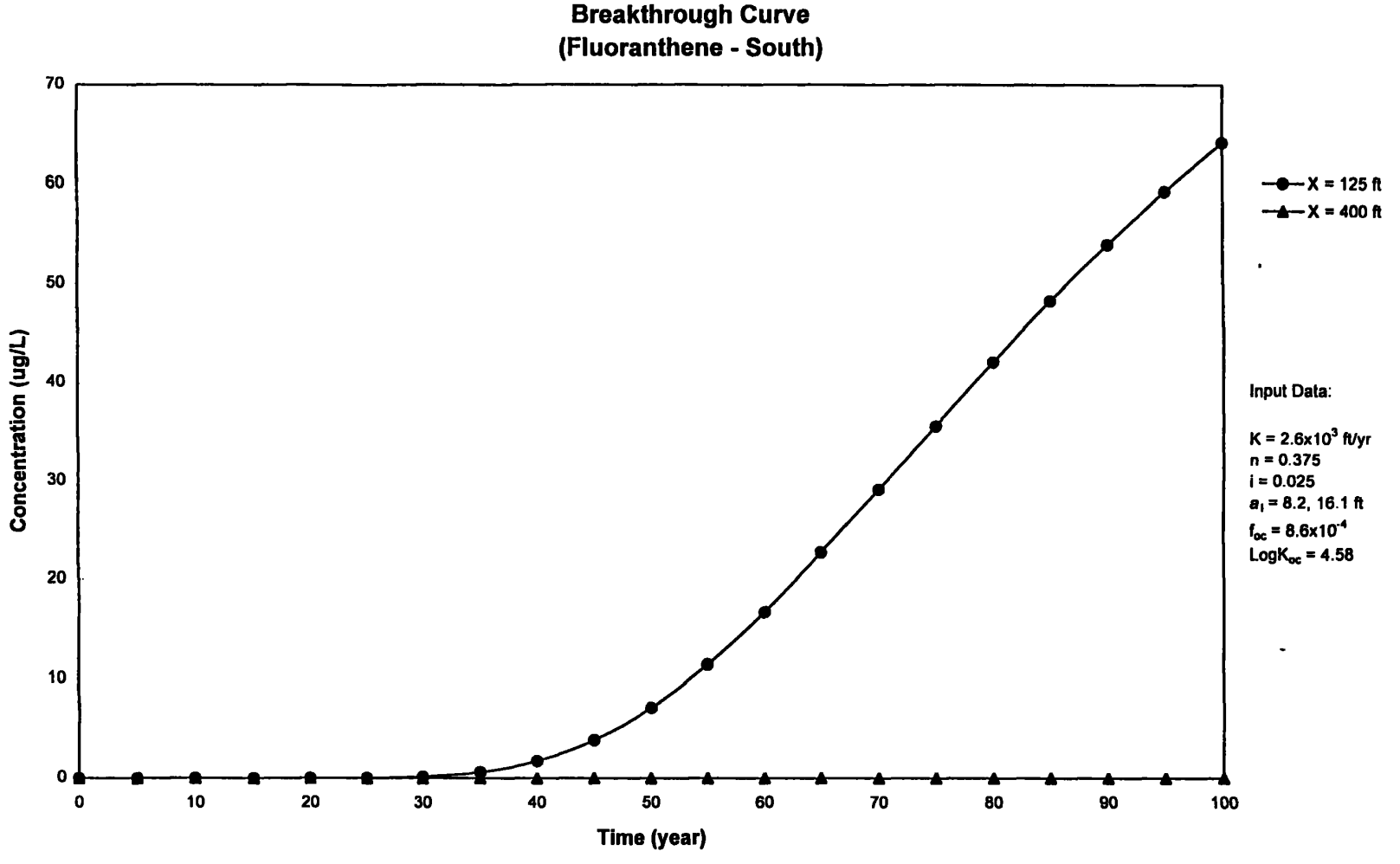

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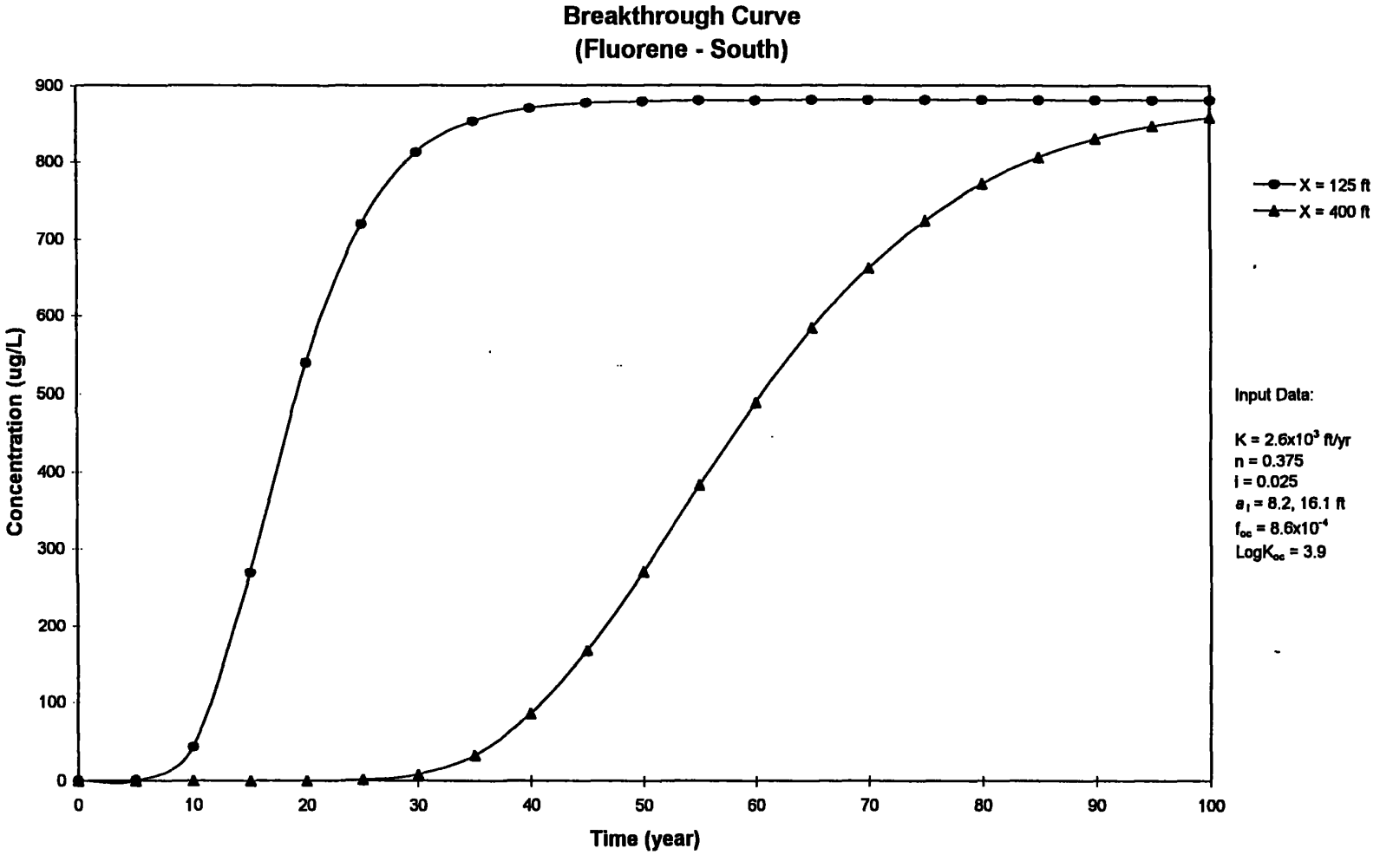

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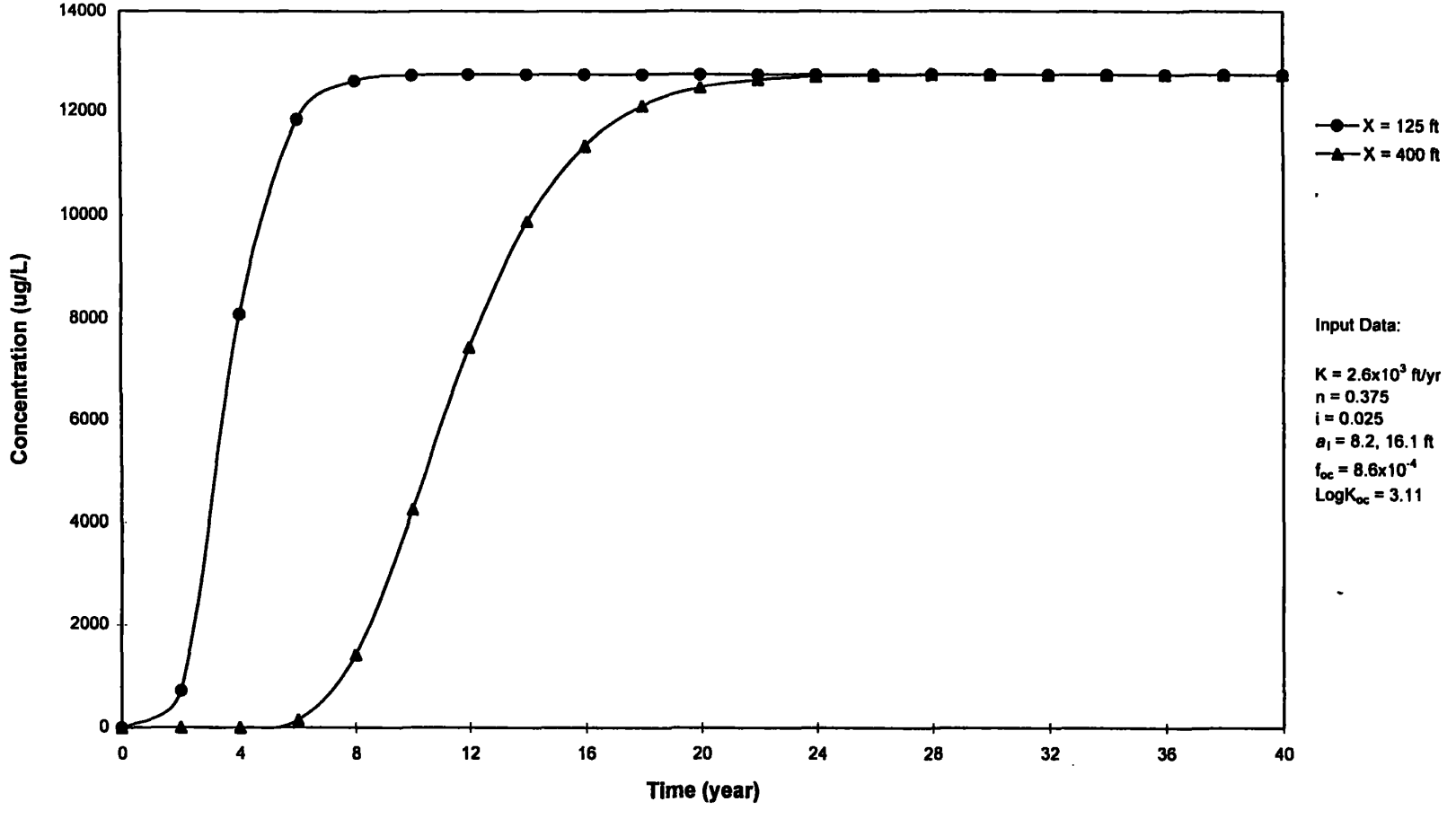
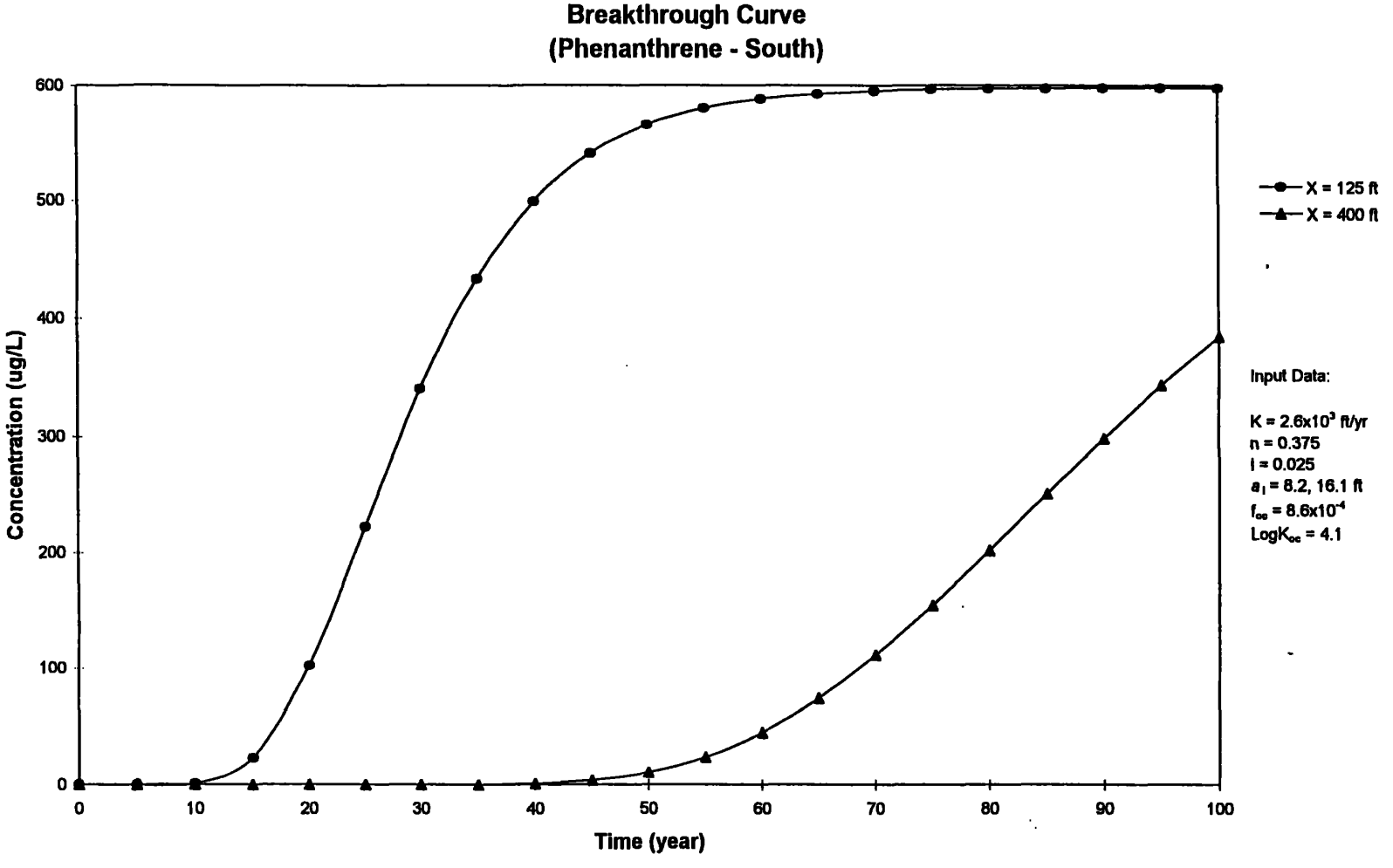
Breakthrough Curve
(Naphthalene - South)



Input Data:

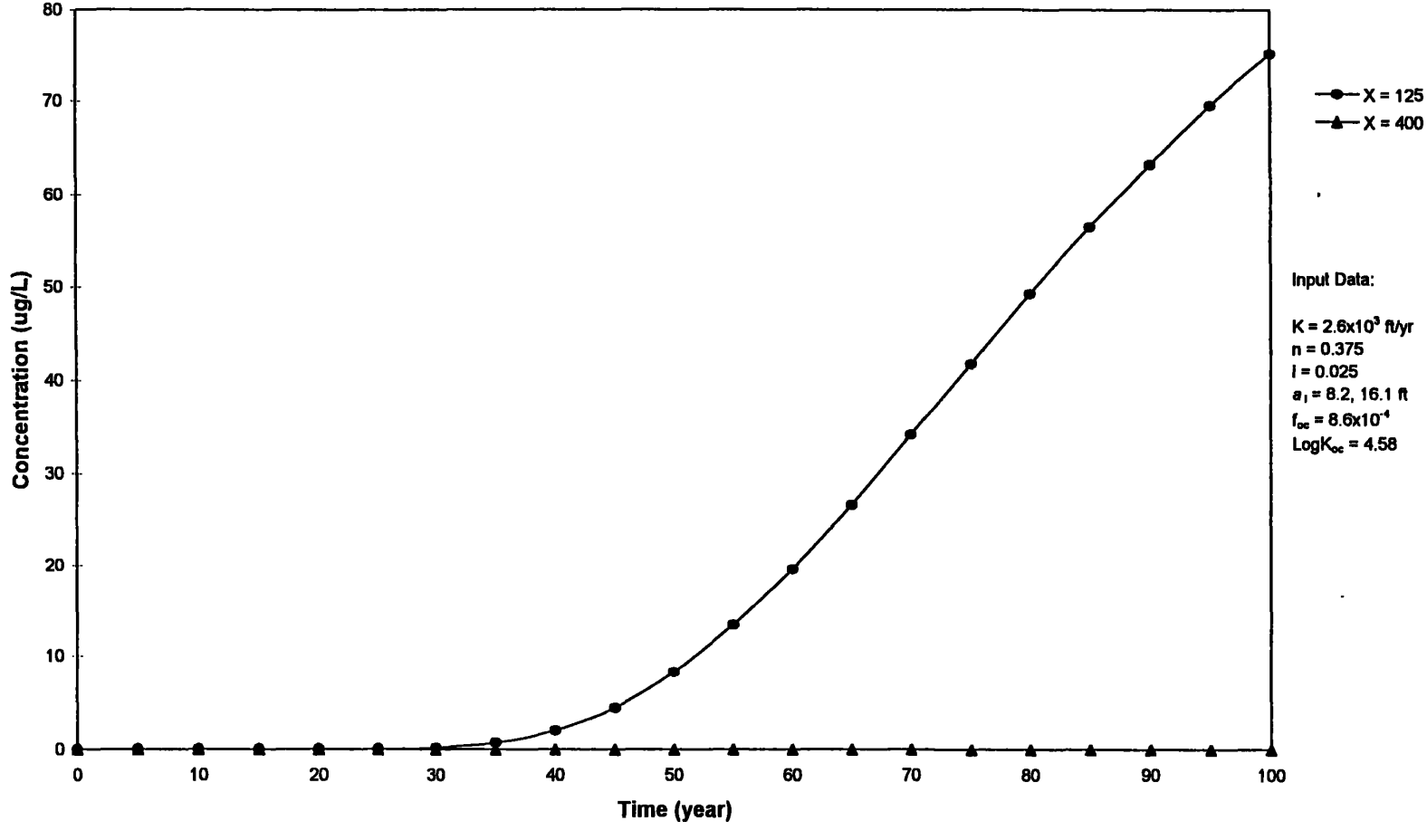
K = 2.6×10^3 ft/yr
n = 0.375
i = 0.025
a_l = 8.2, 16.1 ft
f_{oc} = 8.6×10^{-4}
$LogK_{oc}$ = 3.11

c:\jrh\socav\118-11.xls



c:\jrh\socav\118-12.xls

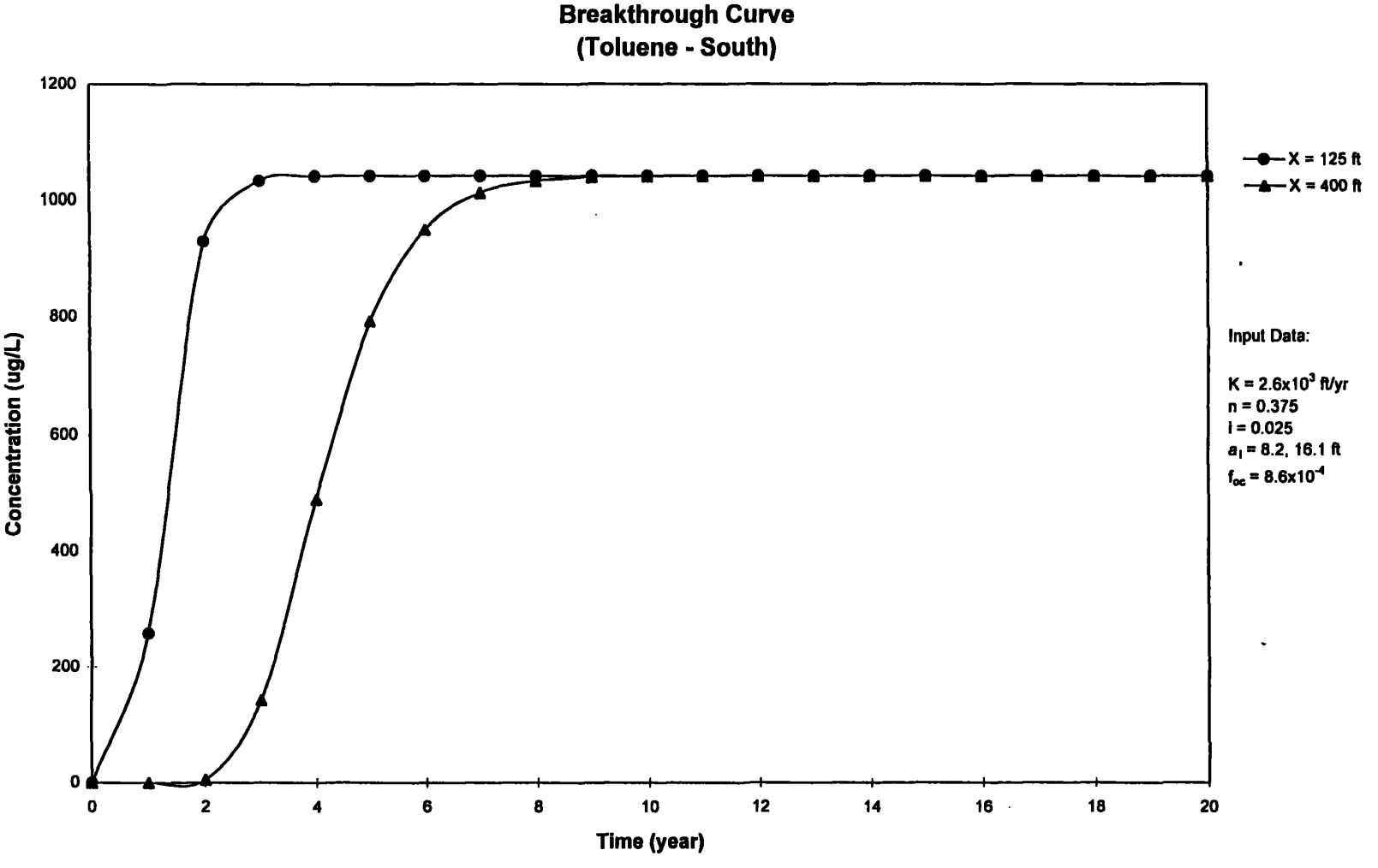
Breakthrough Curve
(Pyrene - South)



Input Data:

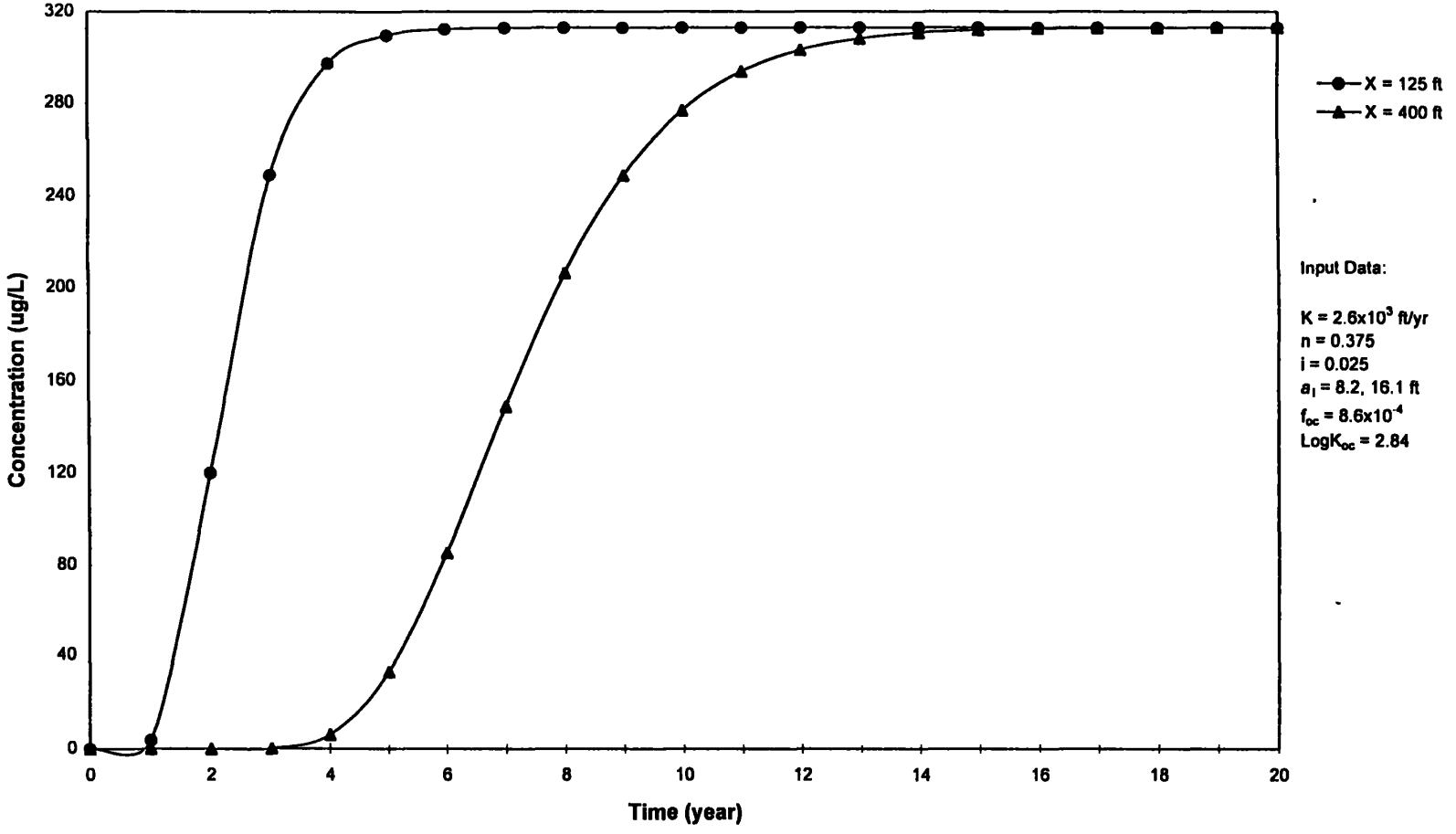
$K = 2.6 \times 10^{3}$ ft/yr
n = 0.375
I = 0.025
a_l = 8.2, 16.1 ft
$f_{oc} = 8.6 \times 10^{-4}$
$\text{Log}K_{oc}$ = 4.58

c:\jrh\socav\118-13.xls



c:\jrh\socav\118-14.xls

Breakthrough Curve
(Xylenes - South)

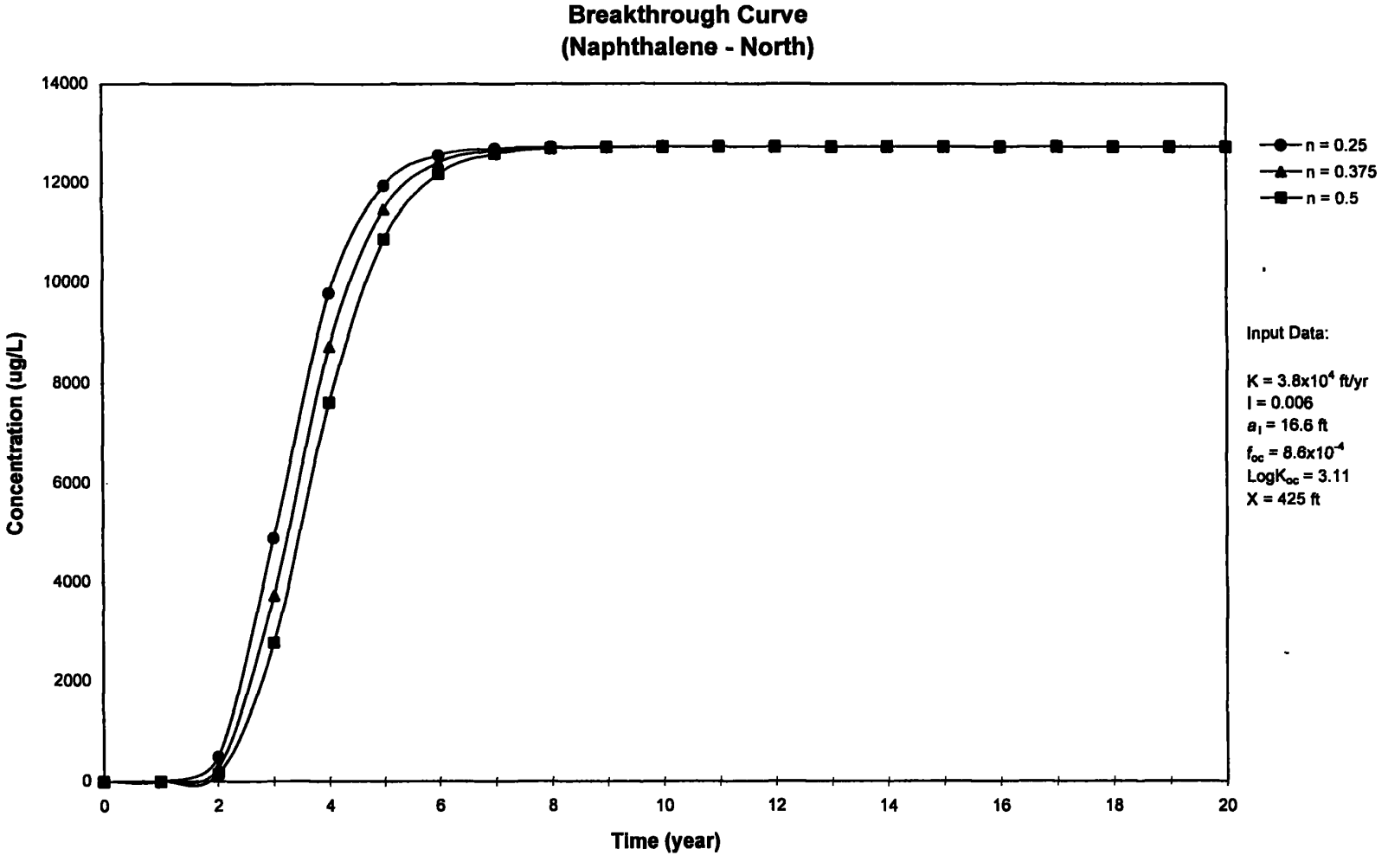


c:\jrh\socav\118-15.xls

APPENDIX E

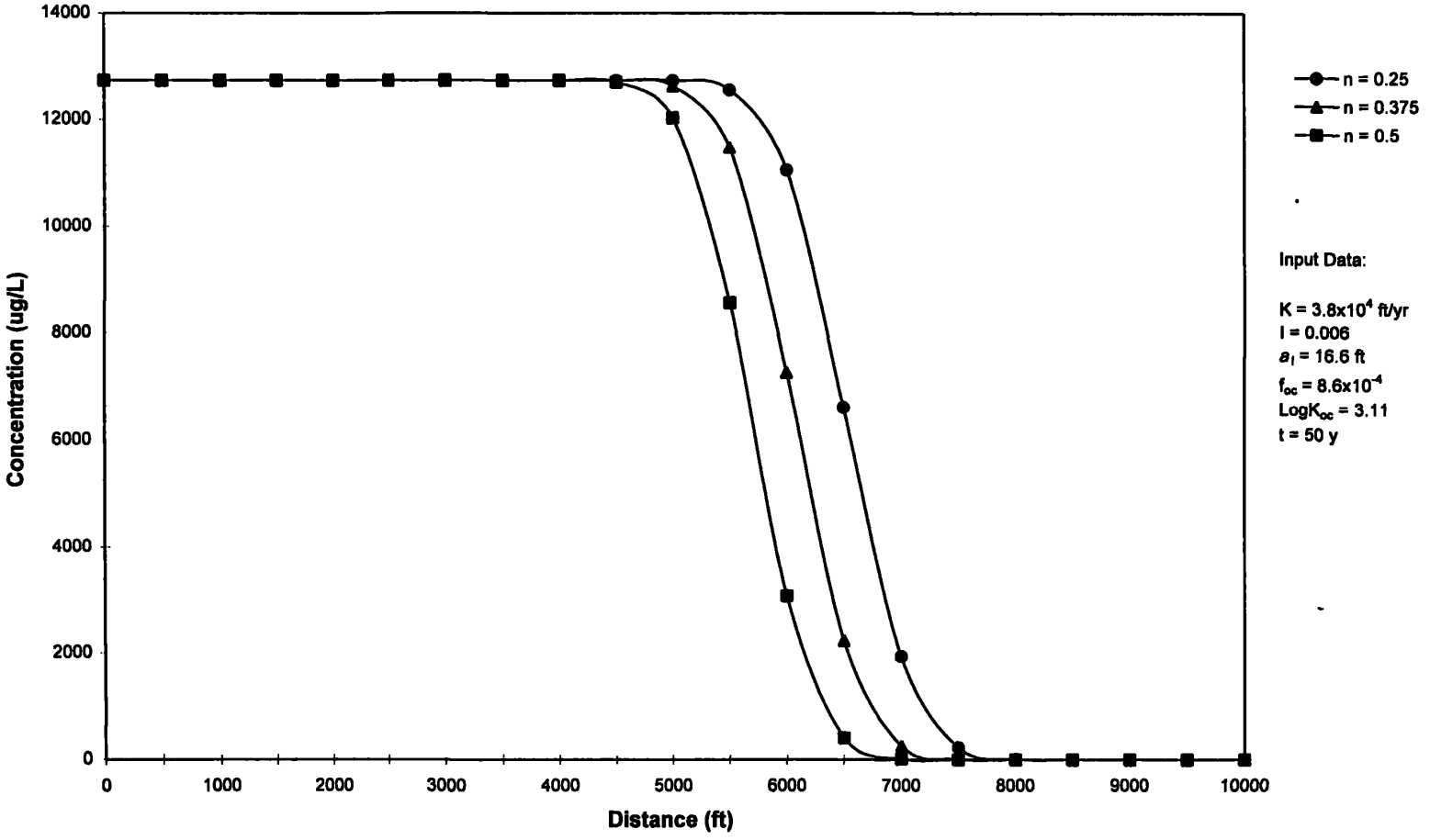
SCENARIO 2 - SENSITIVITY ANALYSIS (NORTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED



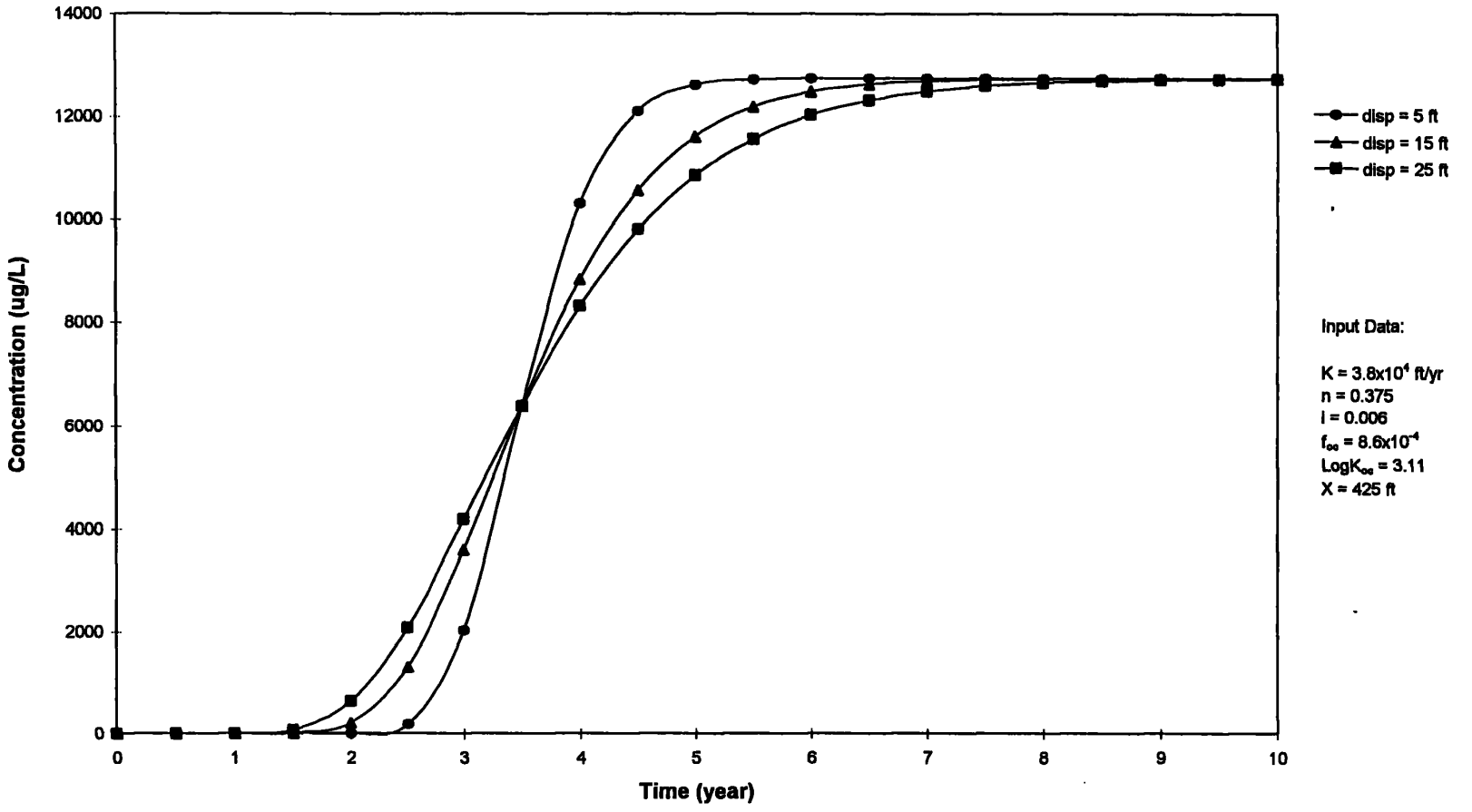
c:\jrh\socav\118-11n.nnn

Breakthrough Curve
(Naphthalene - North)



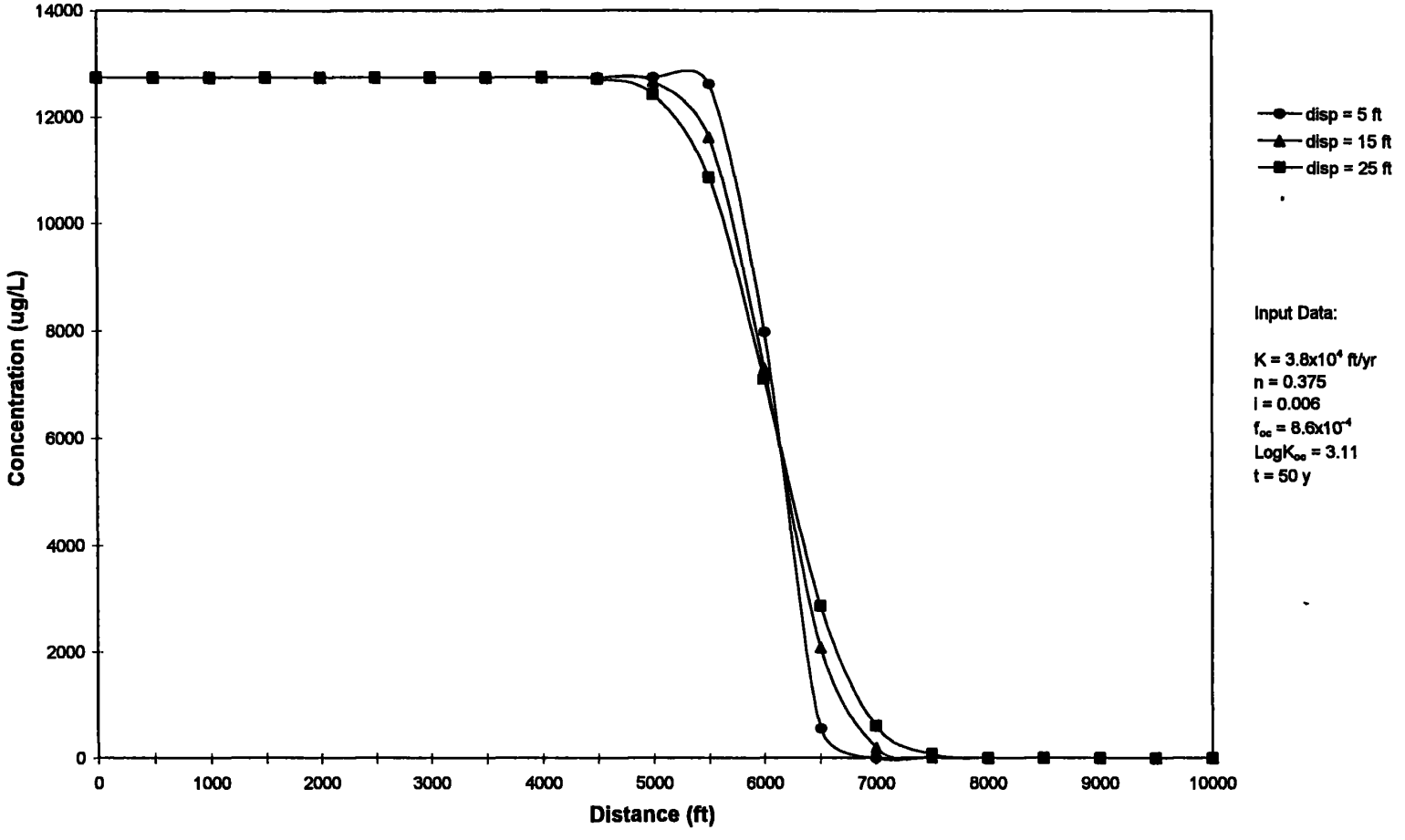
c:\jrh\socav\118-11n.nnn

Breakthrough Curve
(Naphthalene - North)



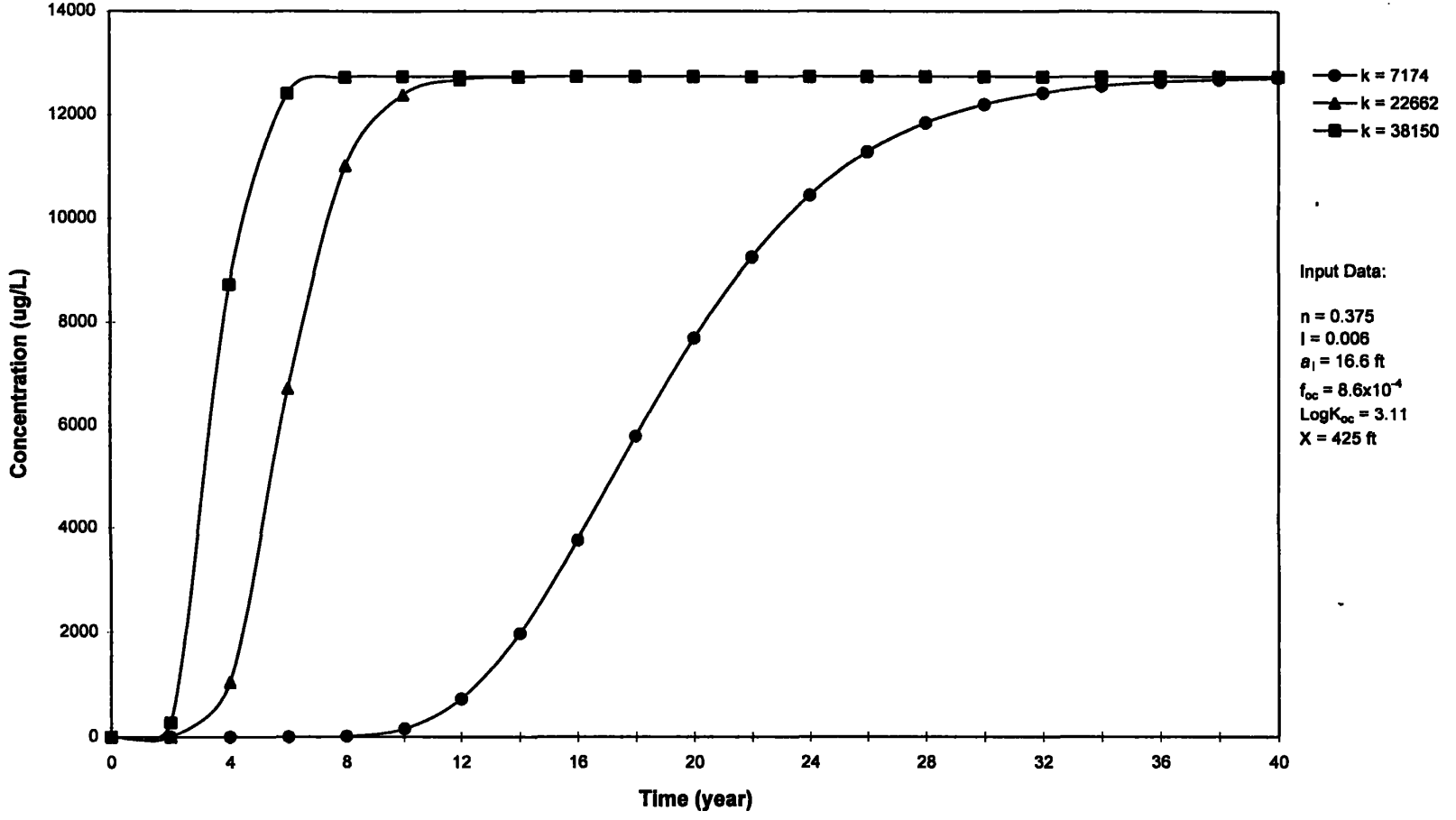
c:\jrh\socav\\118-11n.dsp

Breakthrough Curve
(Naphthalene - North)



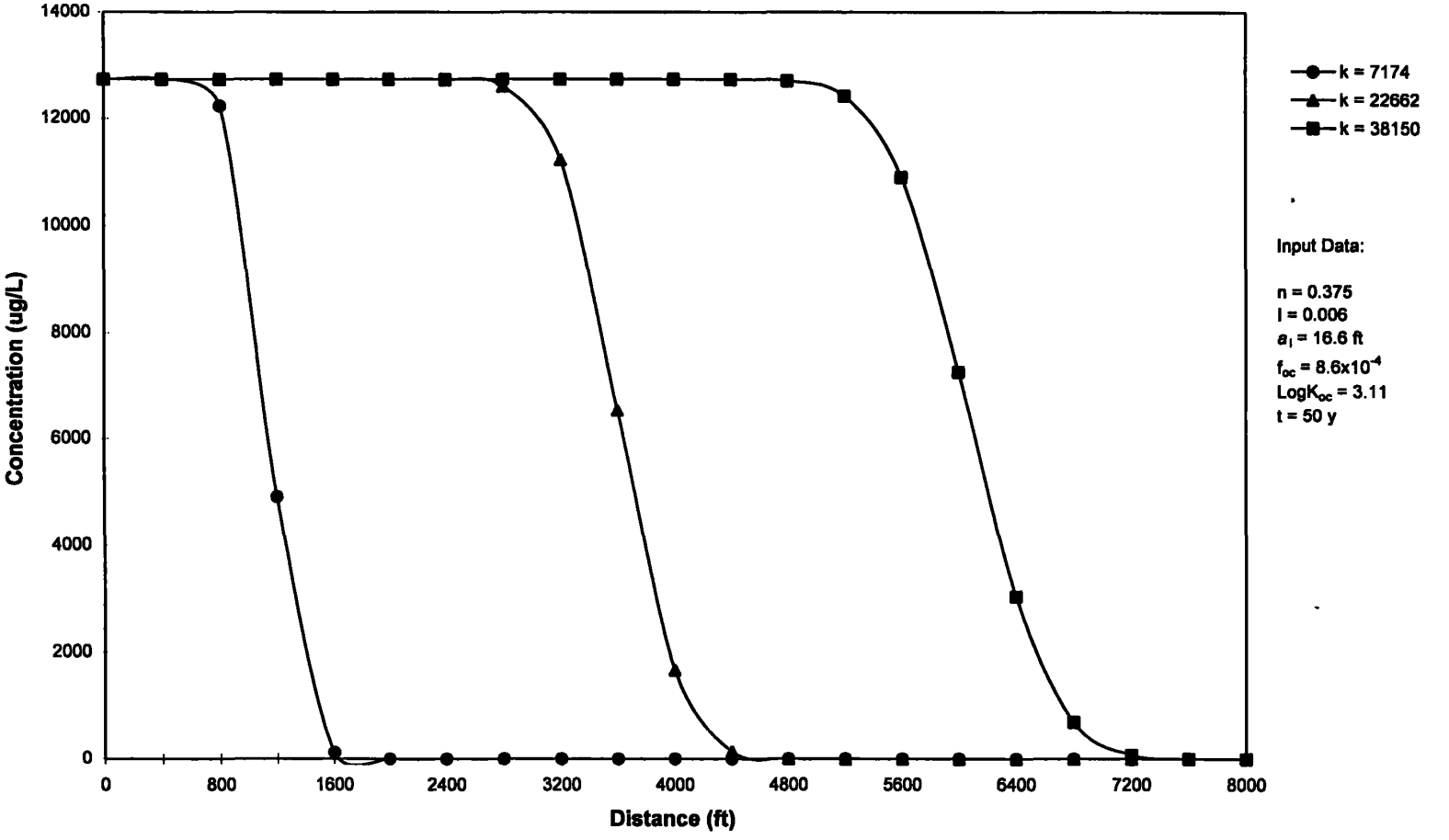
c:\jrh\socav\118-11n.dsp

Breakthrough Curve
(Naphthalene - North)

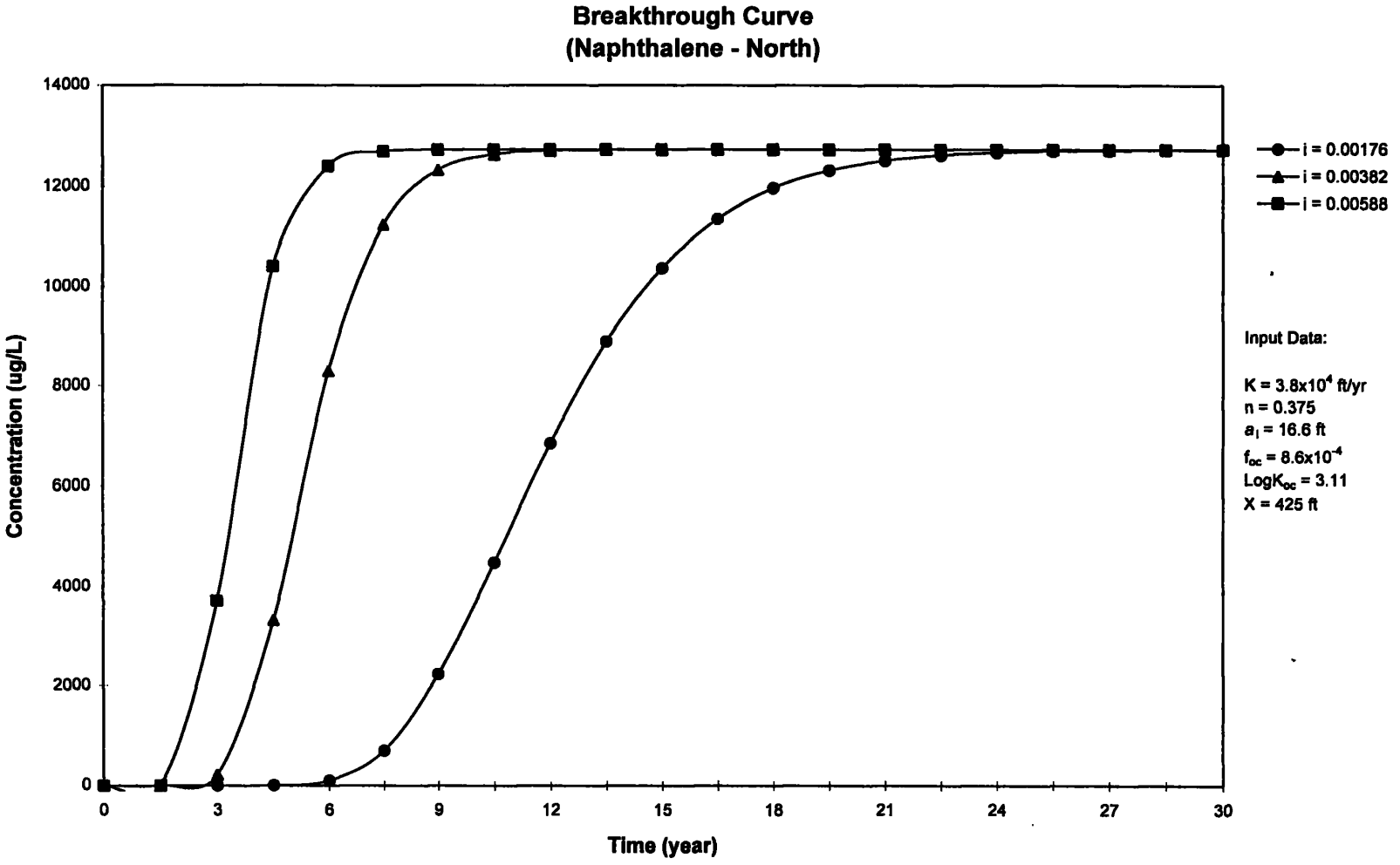


c:\jrh\socav\118-11n.kkk

Breakthrough Curve
(Naphthalene - North)

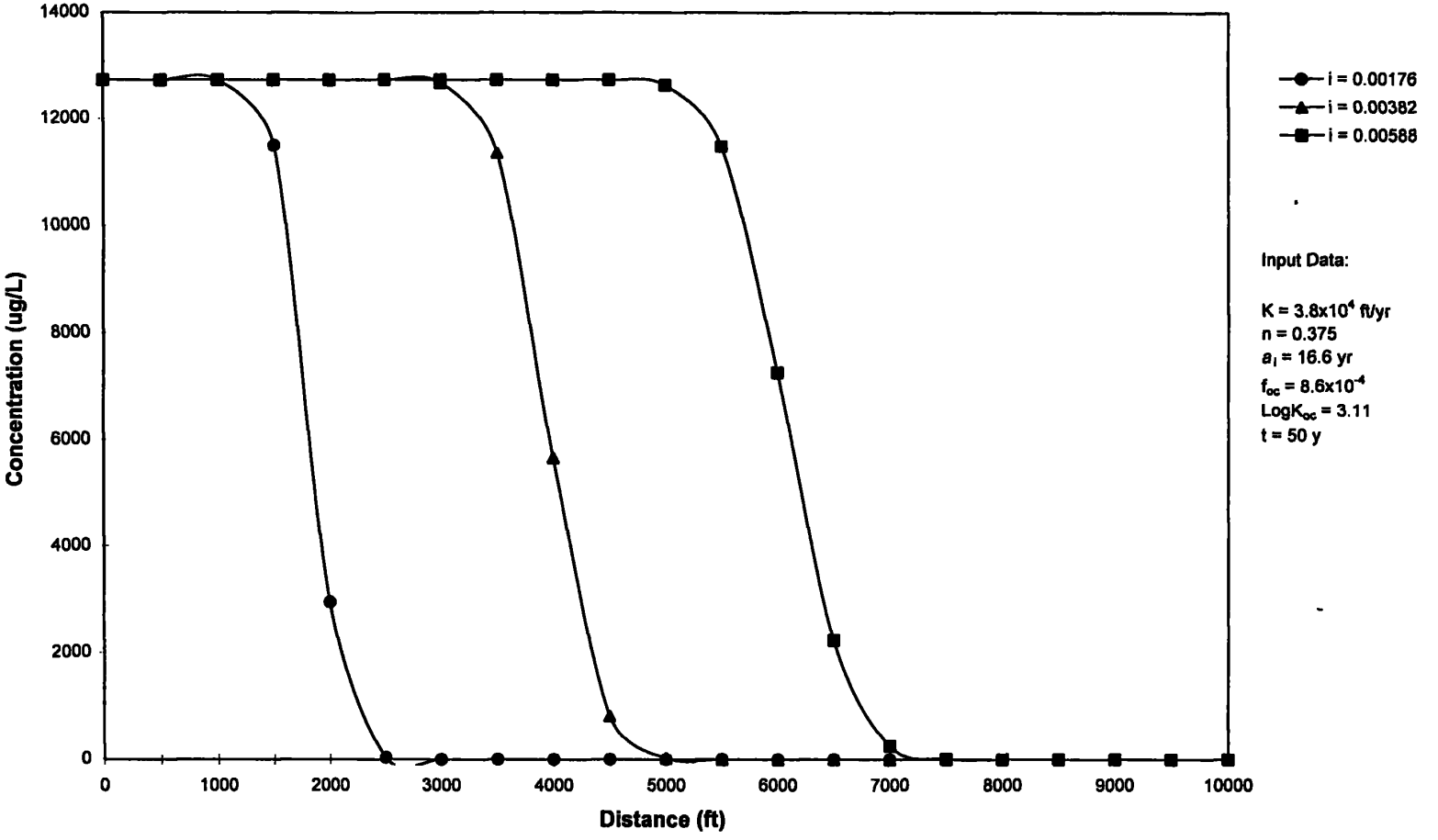


c:\jrh\socav\118-11n.kkk

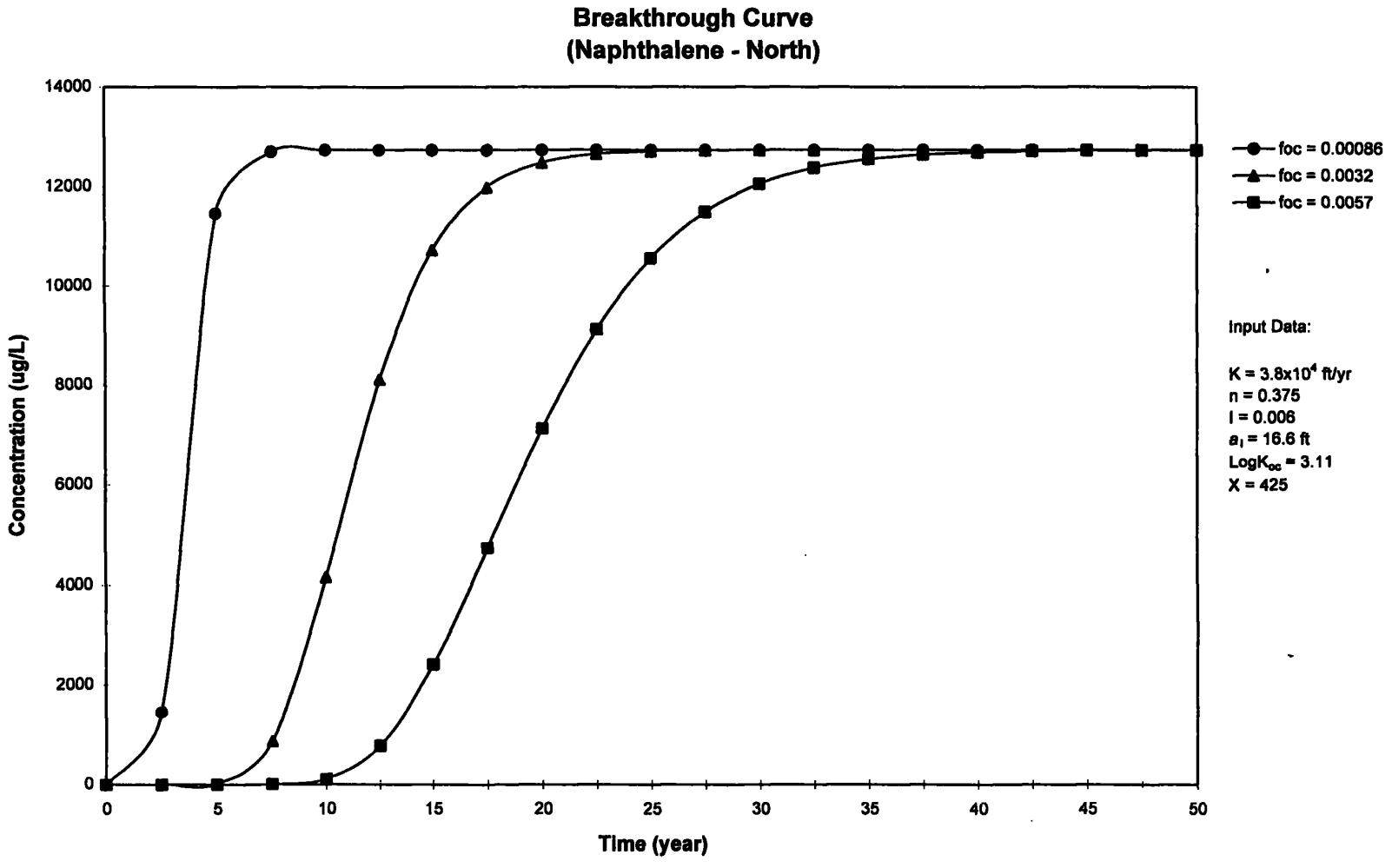


c:\jrh\socav\118-11n.iii

Breakthrough Curve
(Naphthalene - North)

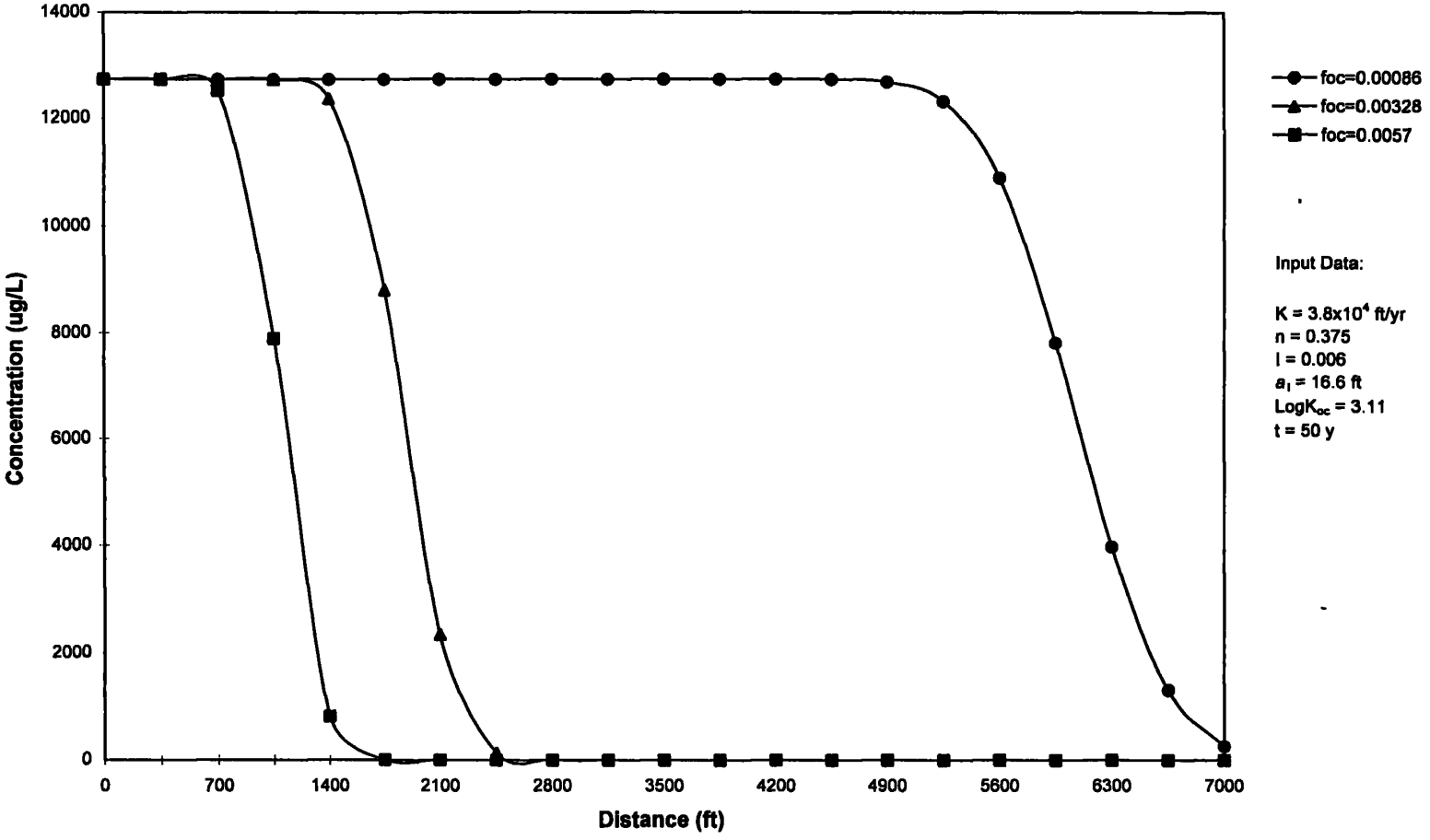


c:\jrh\socav\118-11n.iii



c:\jrh\socav\118-11n.foc

Breakthrough Curve
(Naphthalene - North)

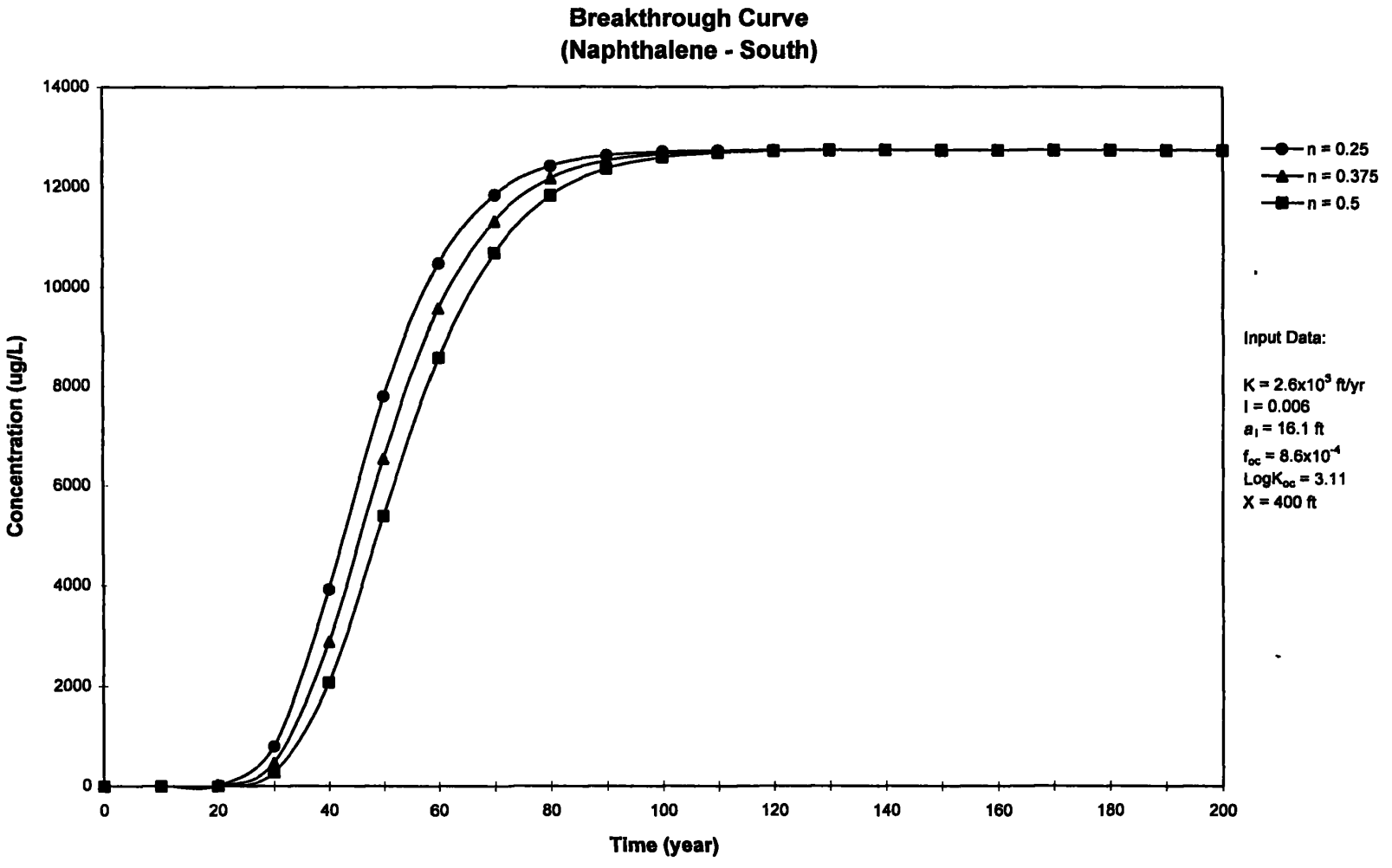


c:\jrh\socav\118-11n.foc

APPENDIX F

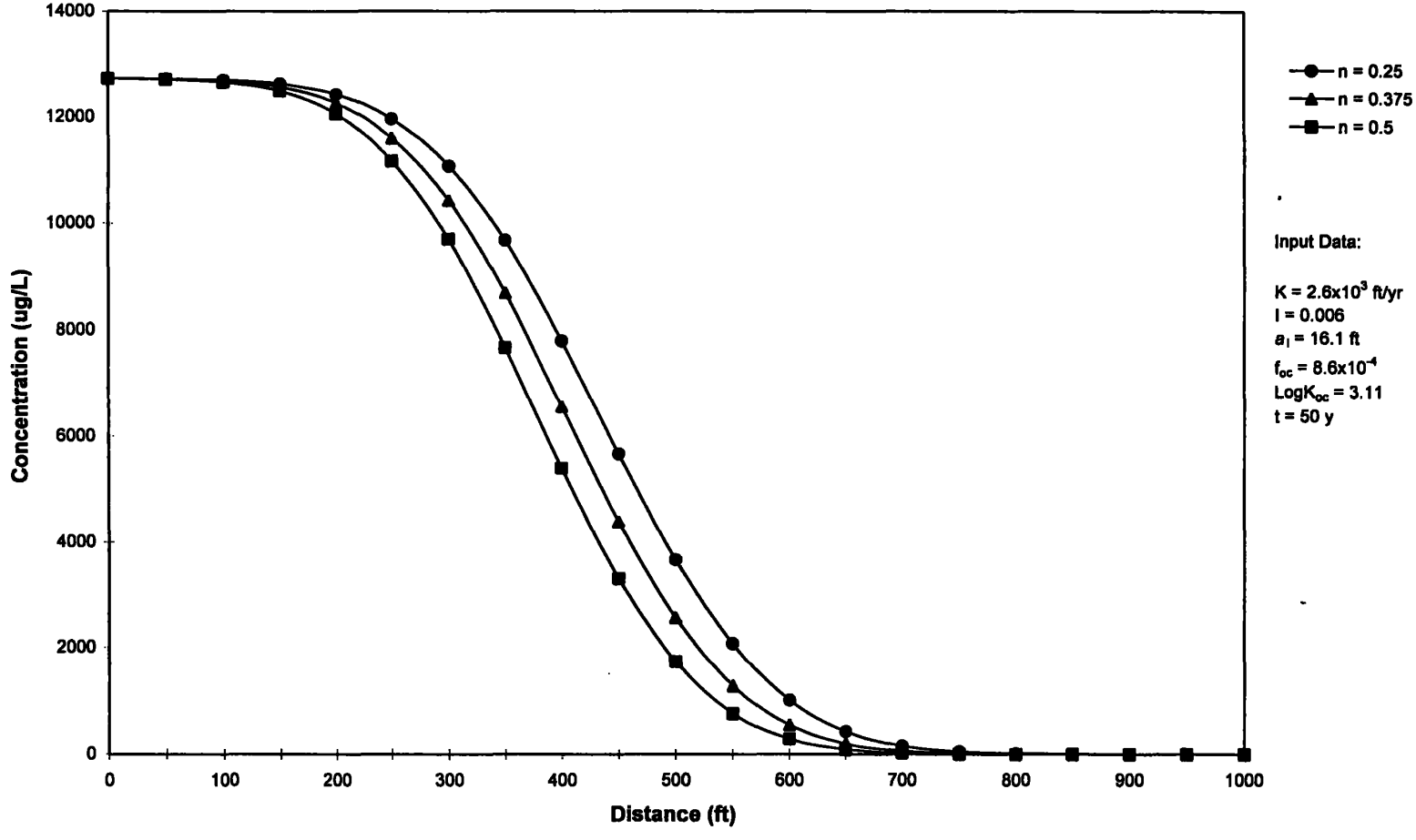
SCENARIO 2 - SENSITIVITY ANALYSIS (SOUTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED



c:\jrh\socav\118-11s.nnn

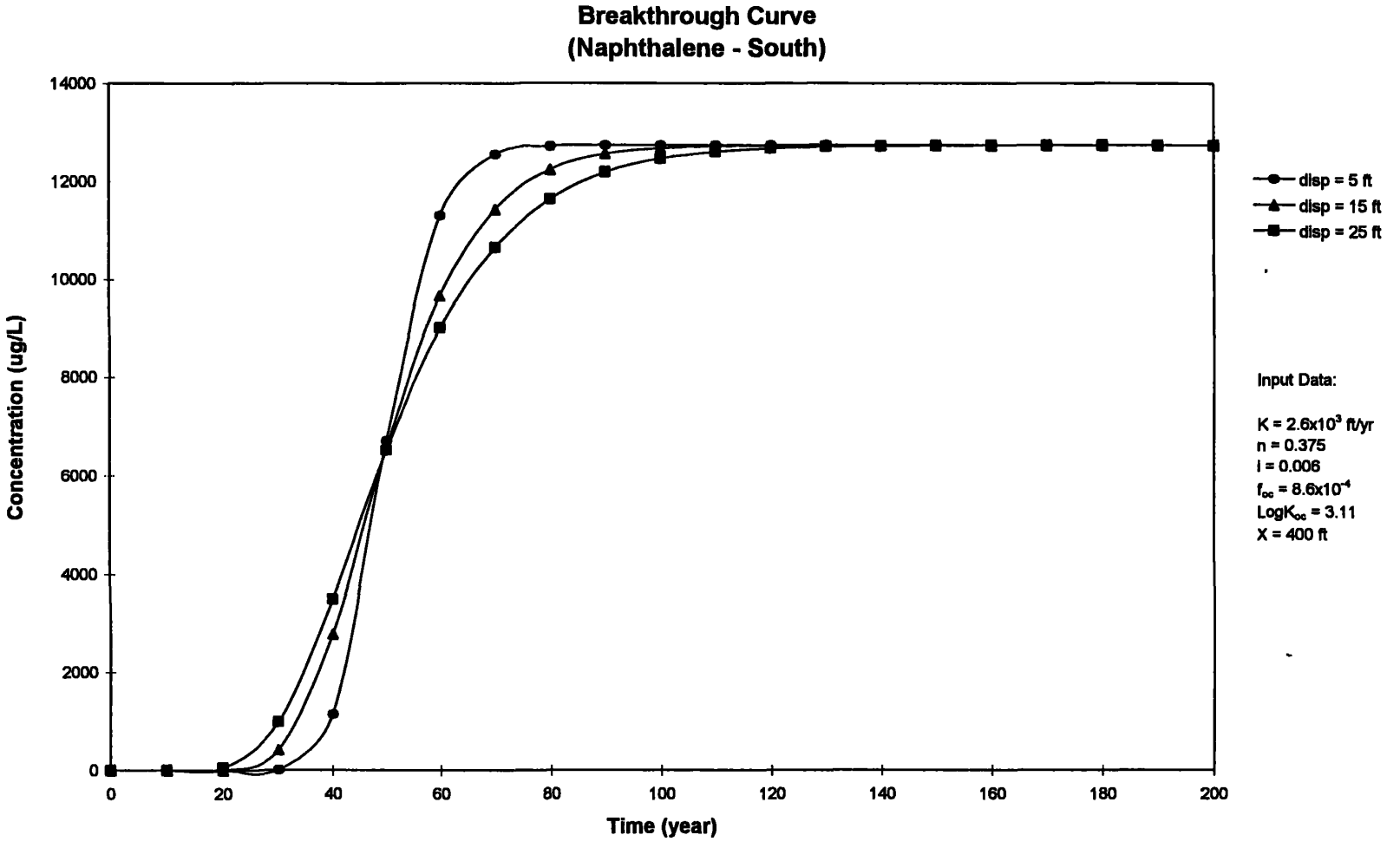
Breakthrough Curve
(Naphthalene - South)



Input Data:

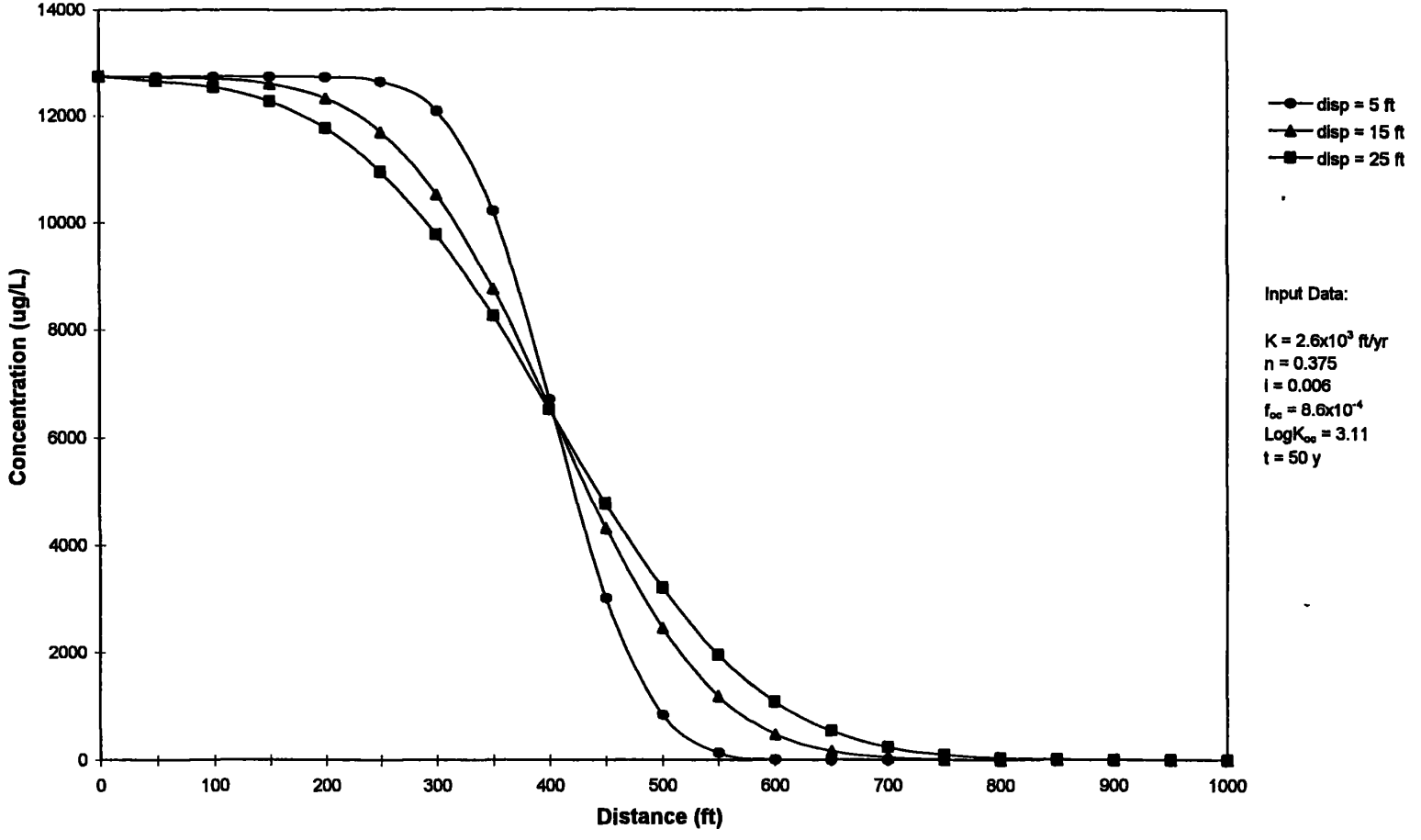
$K = 2.6 \times 10^3$ ft/yr
I = 0.006
a_l = 16.1 ft
$f_{oc} = 8.6 \times 10^{-4}$
$LogK_{oc} = 3.11$
t = 50 y

c:\jrh\socav\118-11s.nnn

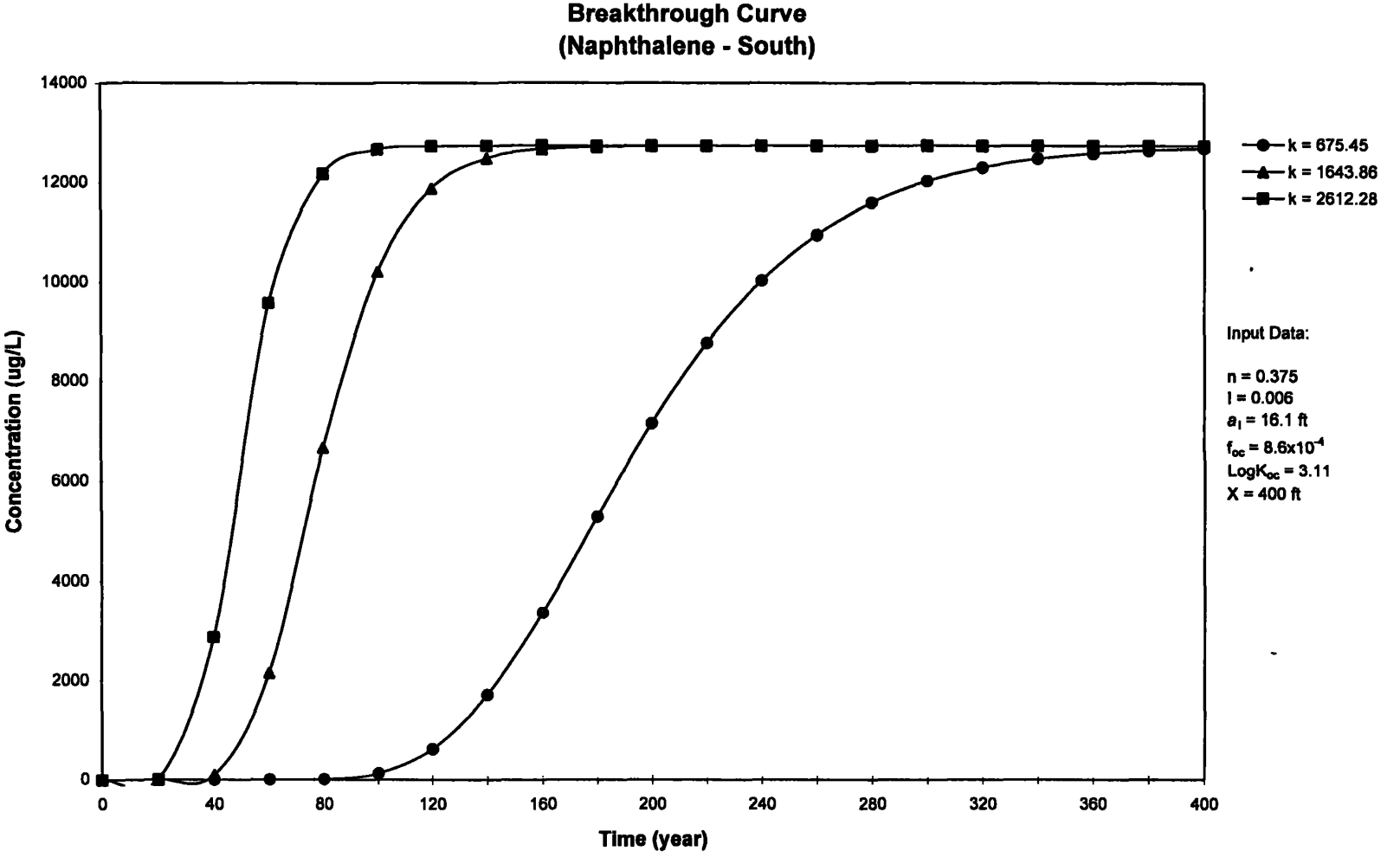


c:\jrh\socav\\118-11s.dsp

Breakthrough Curve
(Naphthalene - South)

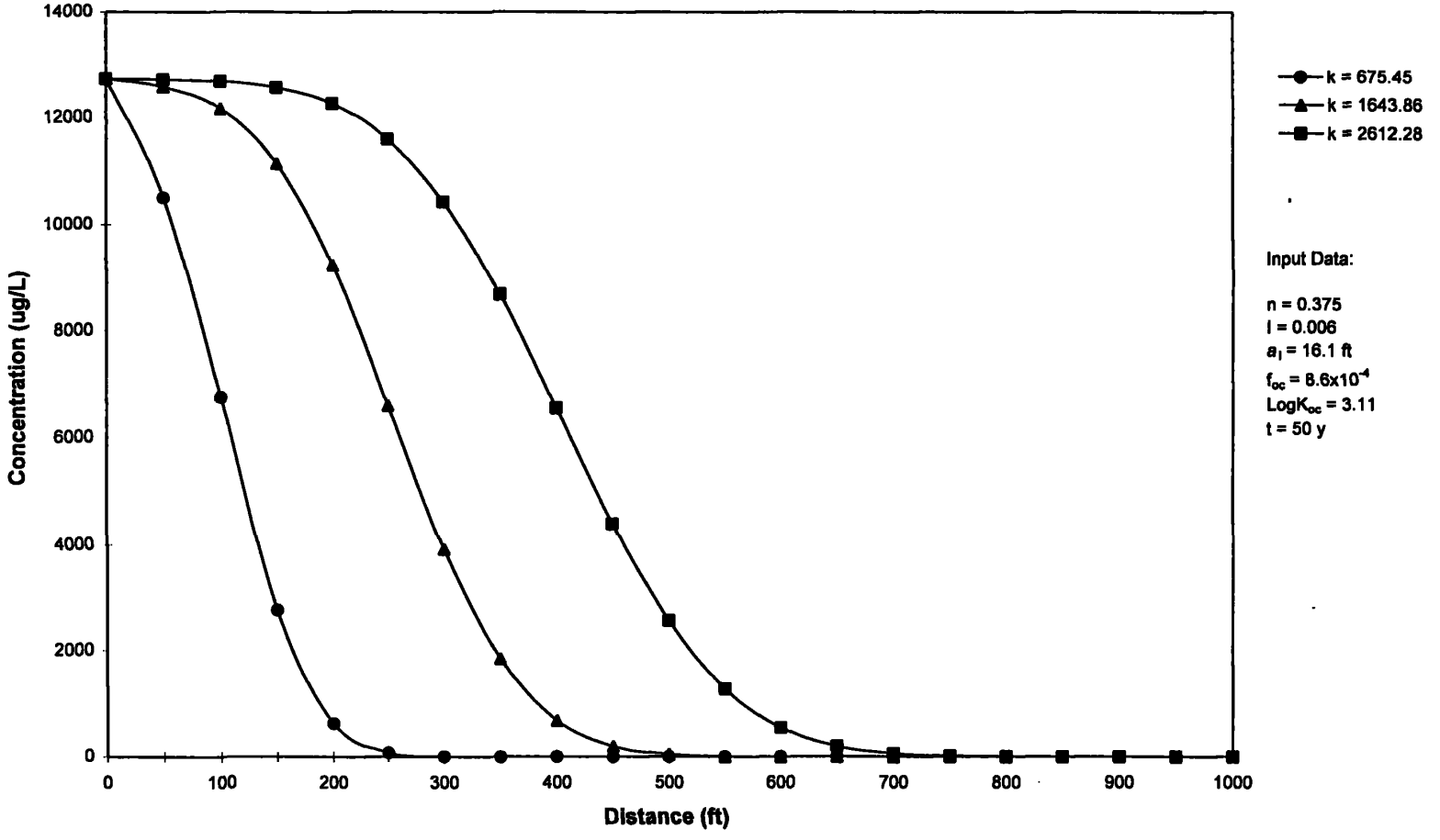


c:\jrh\socav\118-11s.dsp

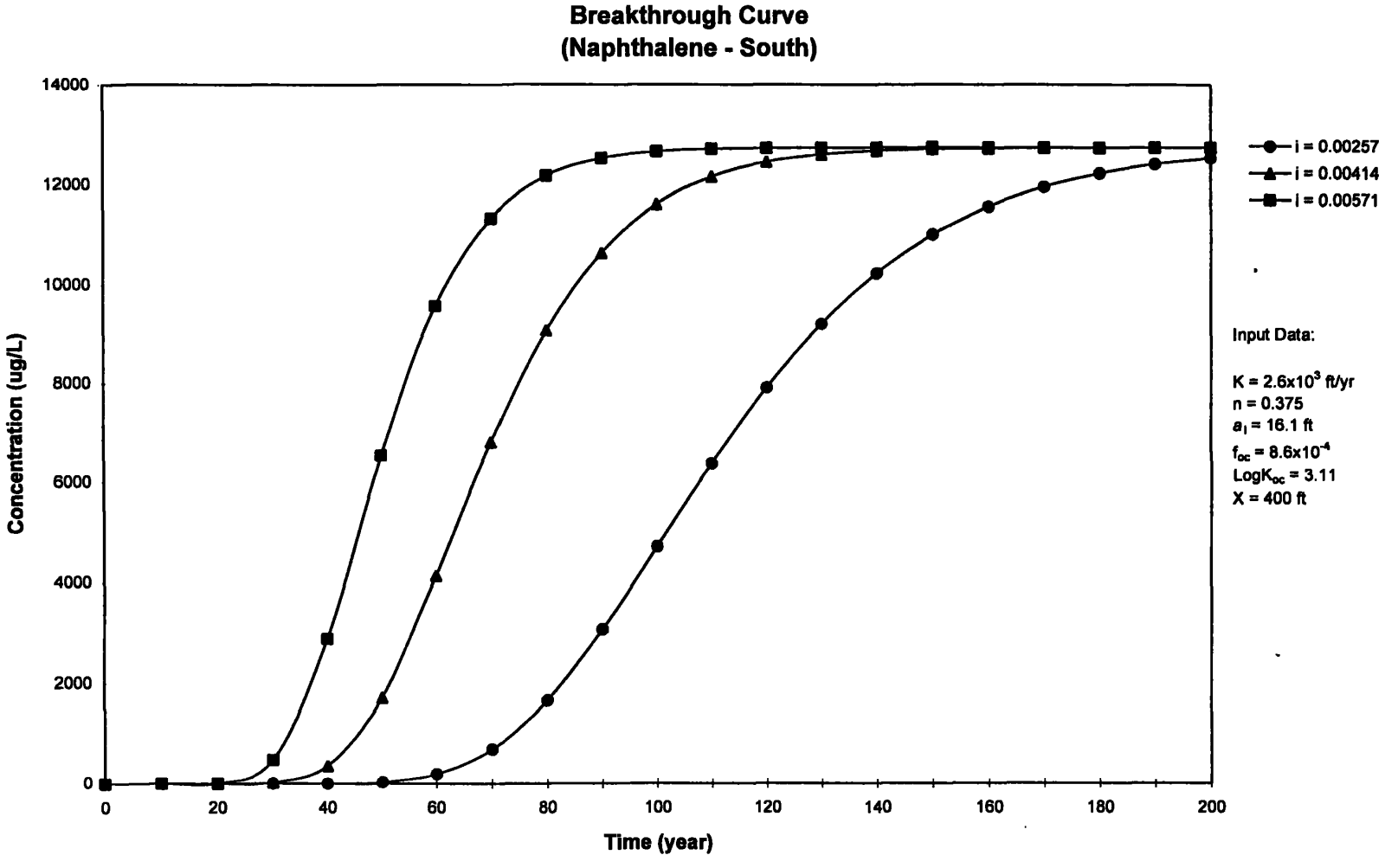


c:\jrh\socav\118-11s.kkk

Breakthrough Curve
(Naphthalene - South)

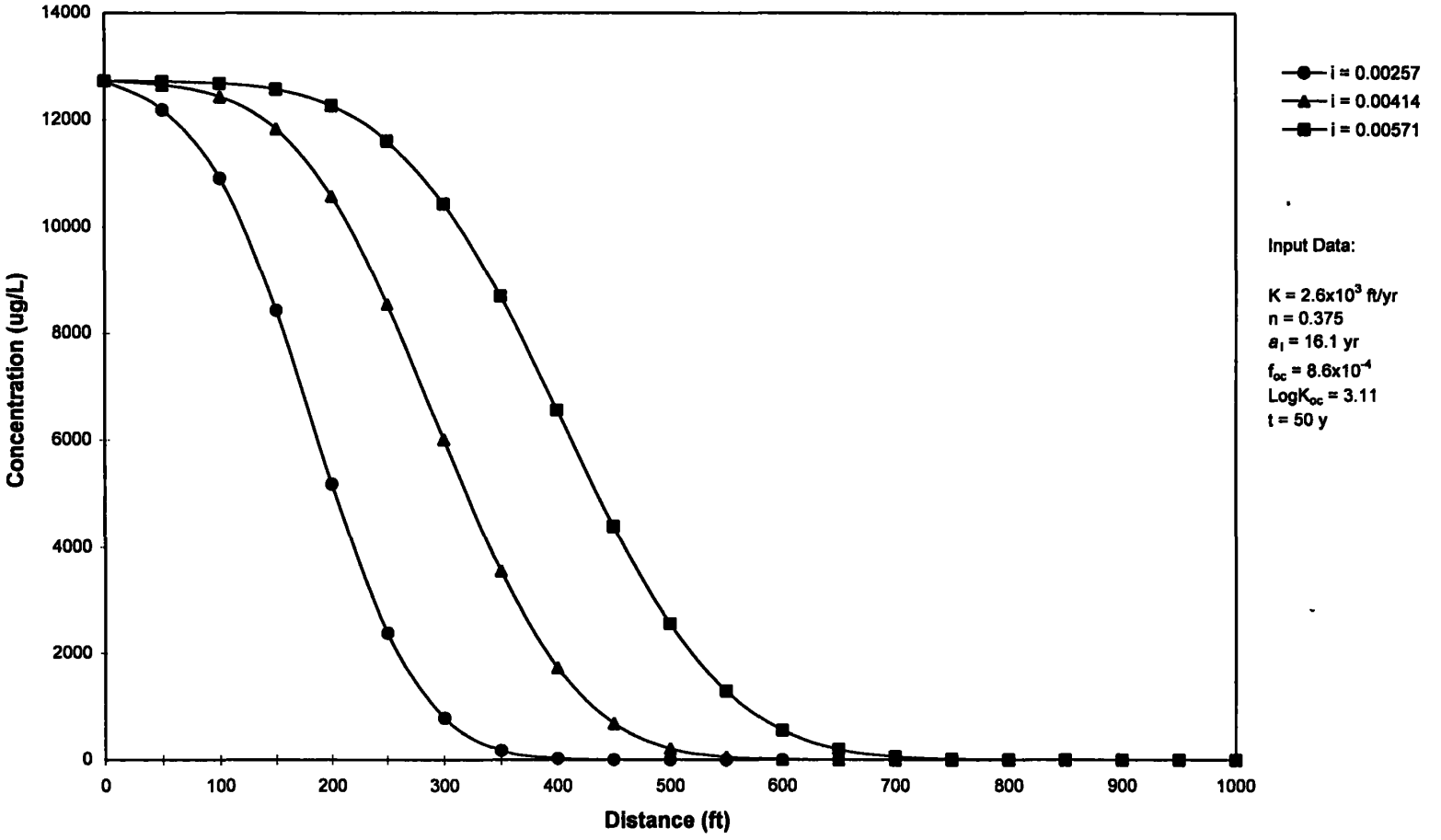


c:\jrh\socav\118-11s.kkk



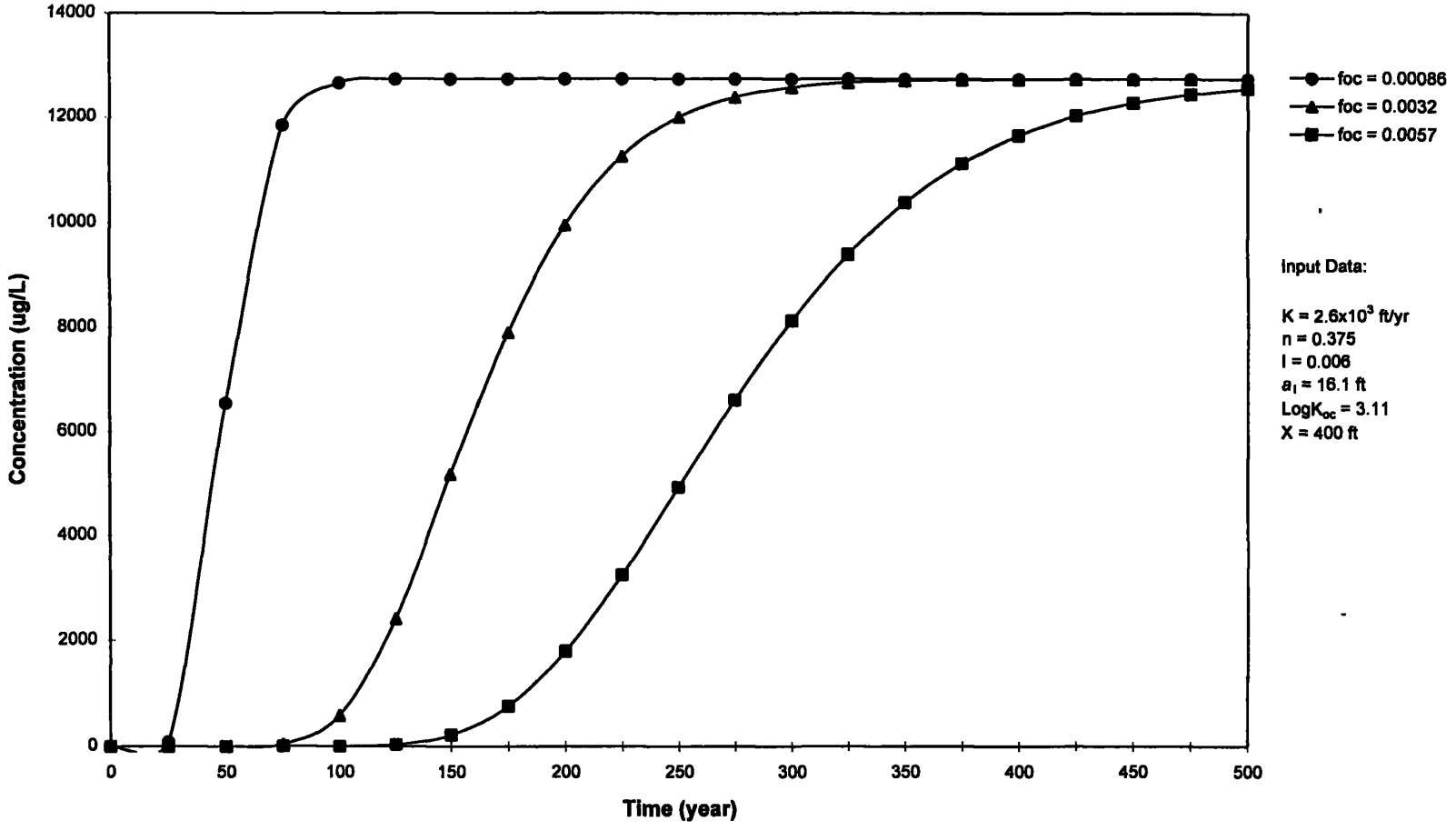
c:\jrh\socav\118-11s.iii

Breakthrough Curve
(Naphthalene - South)



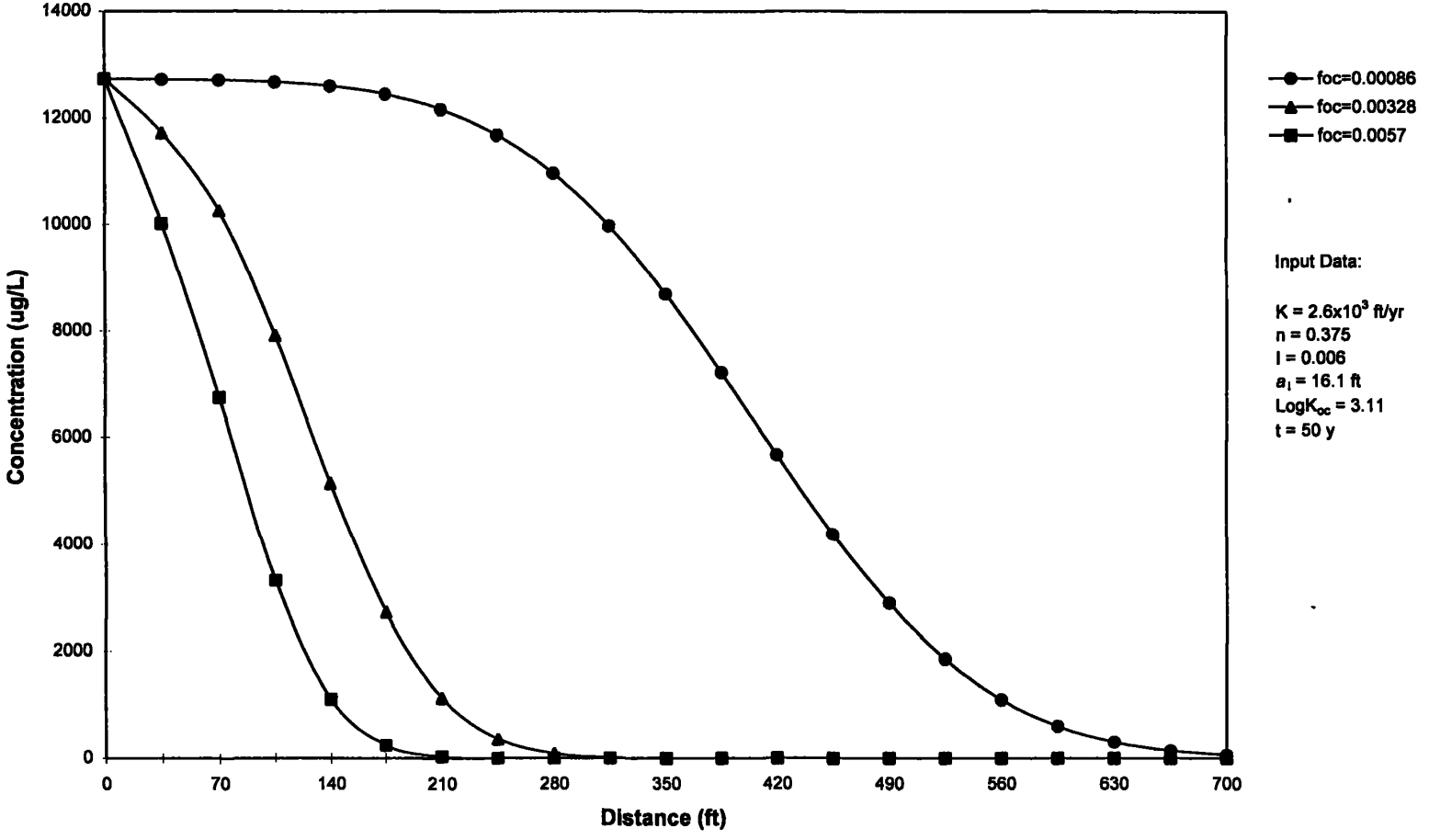
c:\jrh\socav\118-11s.iii

Breakthrough Curve
(Naphthalene - South)



c:\jrh\socav\118-11s.foc

Breakthrough Curve
(Naphthalene - South)



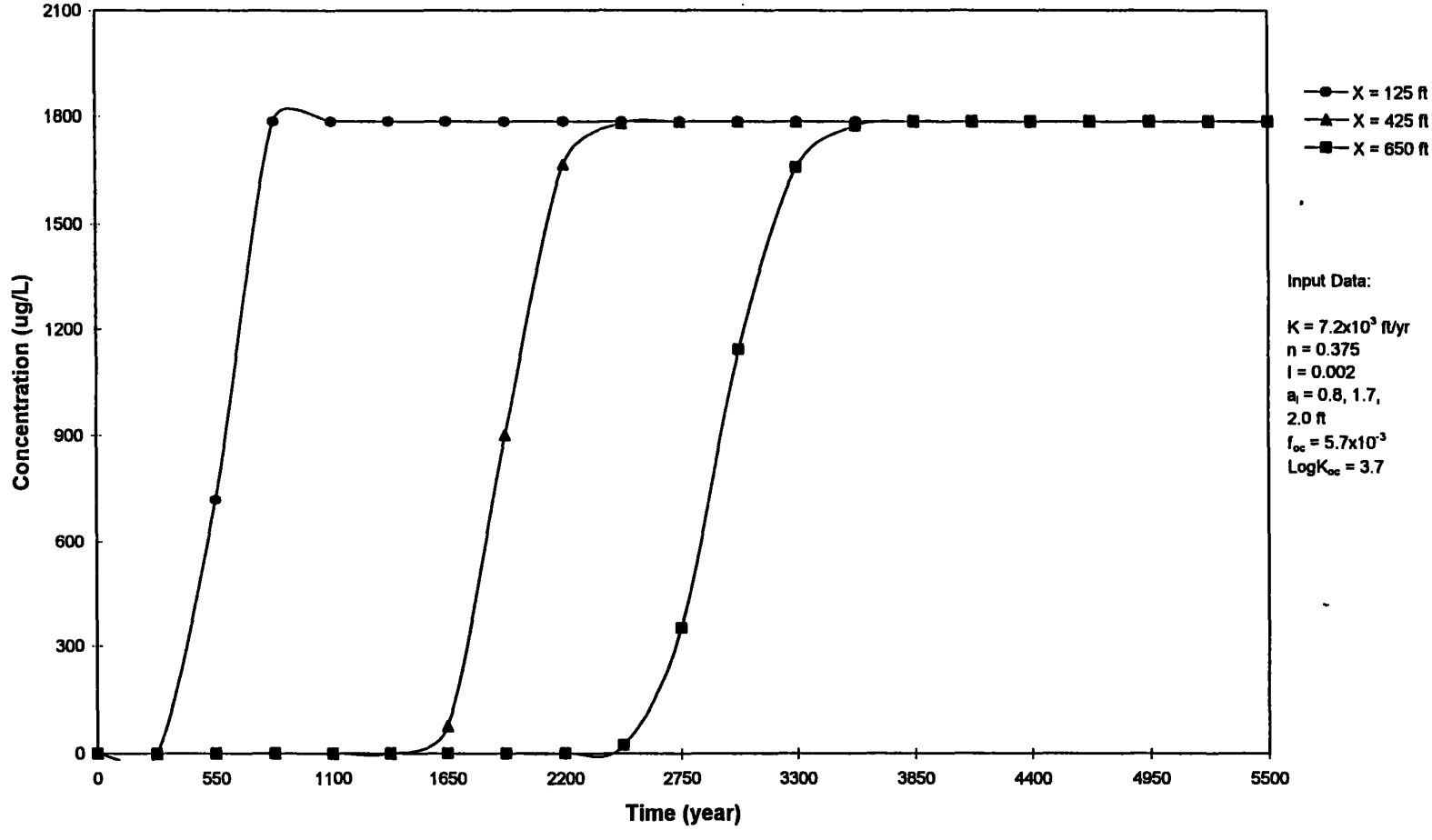
c:\jrh\socav\118-11s.foc

APPENDIX G

SCENARIO 3 - BEST CASE SIMULATIONS (NORTHERN AREA)

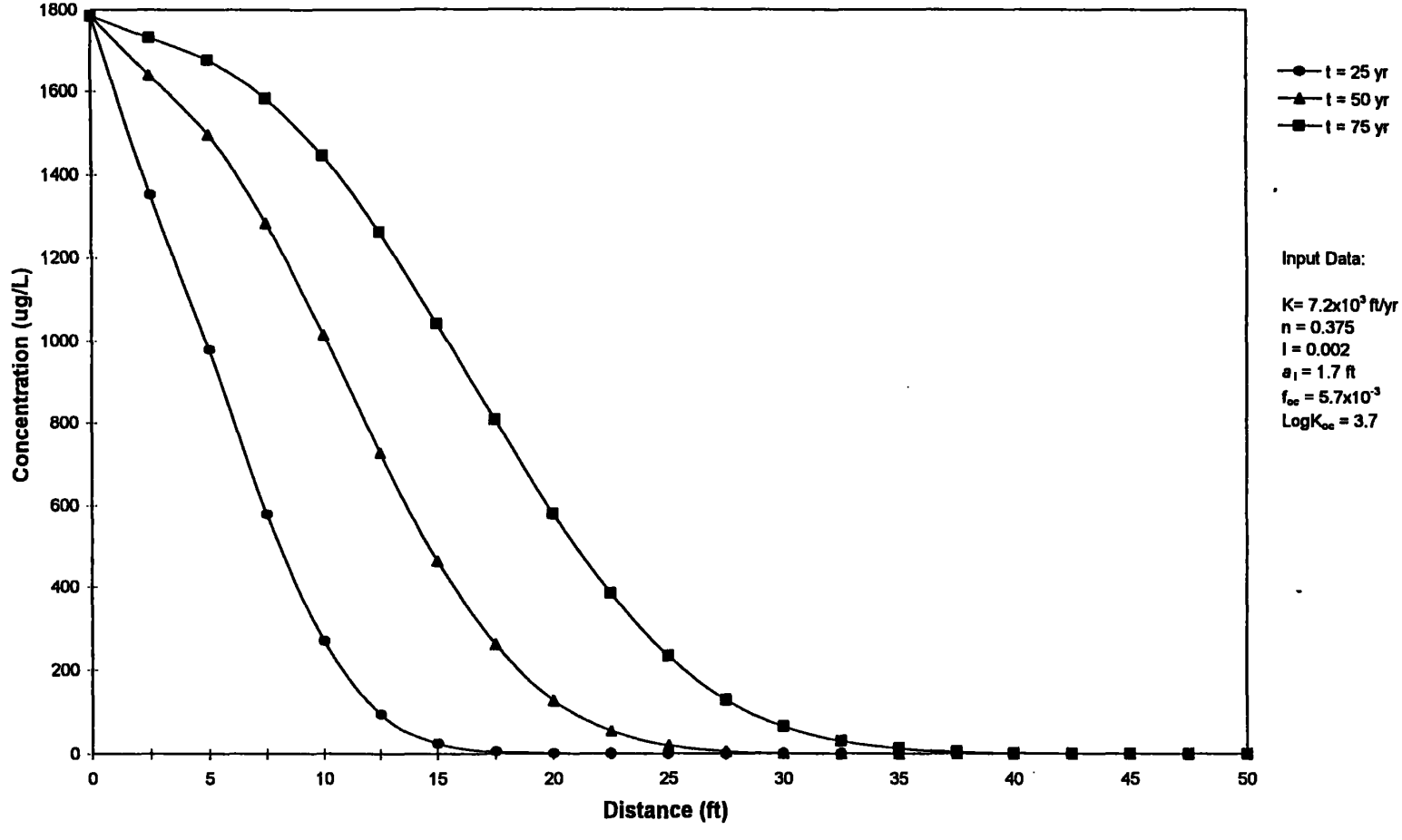
KEY ENVIRONMENTAL INCORPORATED

Breakthrough Curve
(Acenaphthene - North)

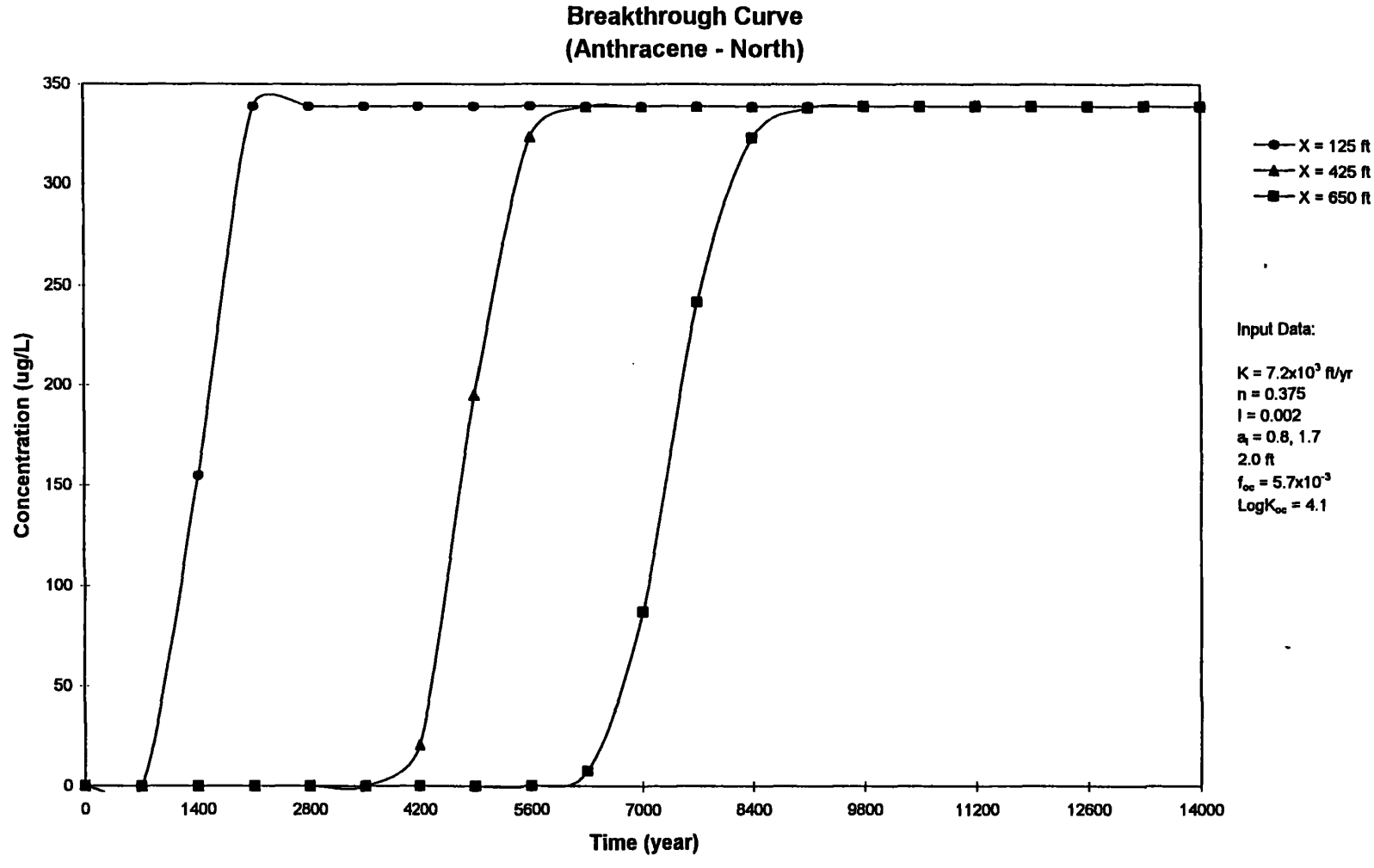


c:\jrh\socav\118-01nc.no

Breakthrough Curve
(Acenaphthene - North)

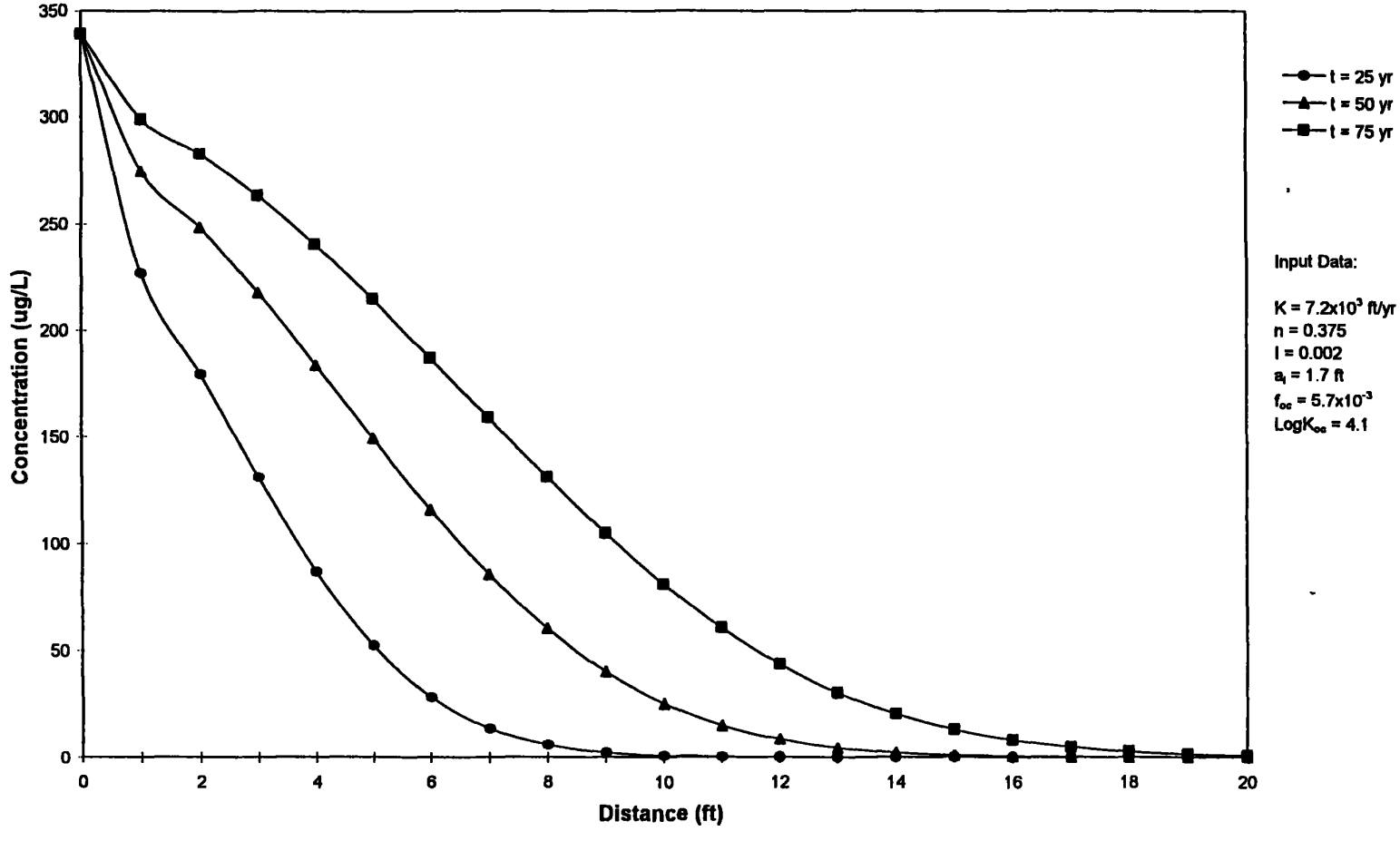


c:\jrh\socav\118-01nc.no



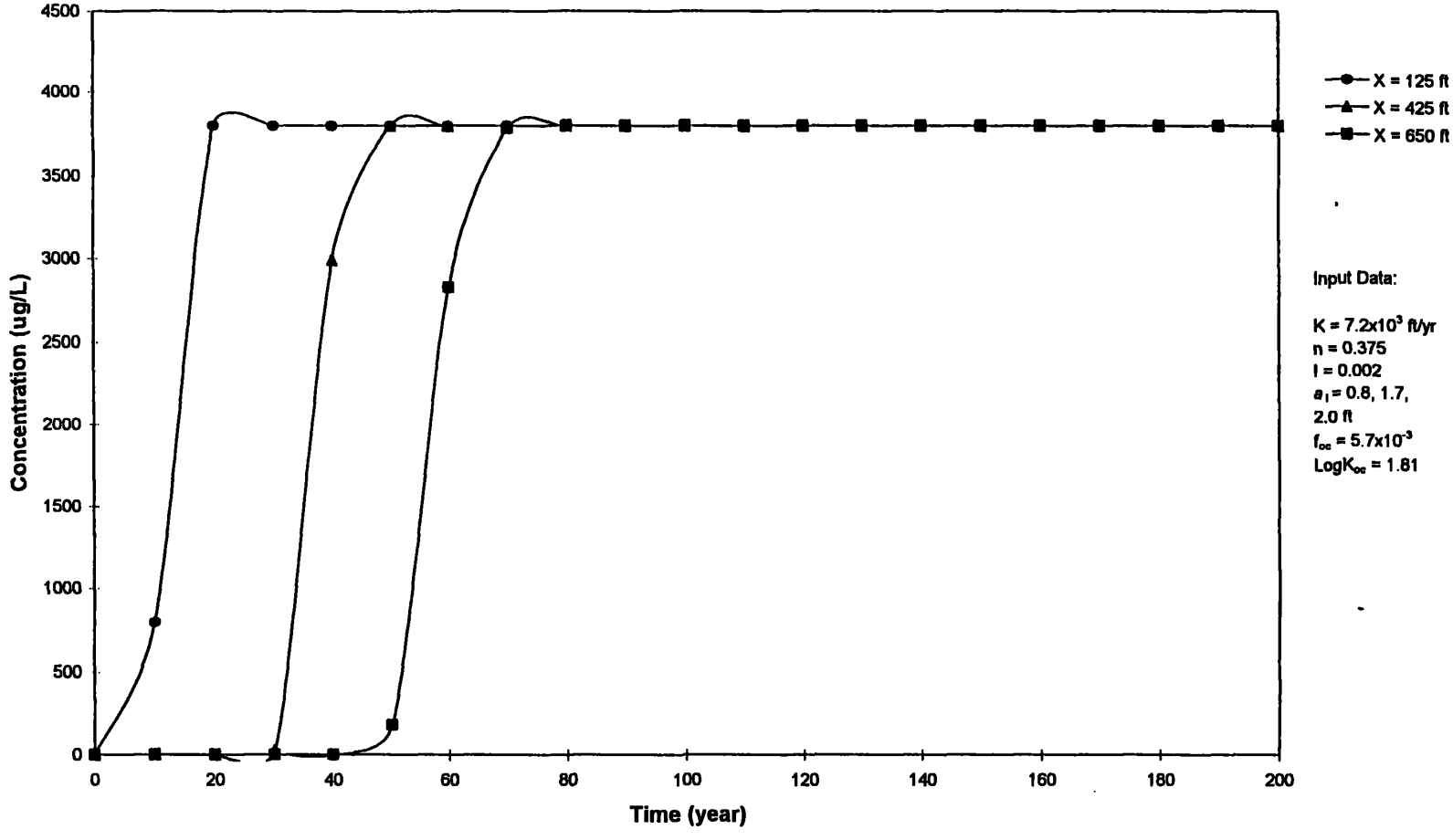
c:\jrh\socav\118-02nc.no

Breakthrough Curve
(Anthracene - North)



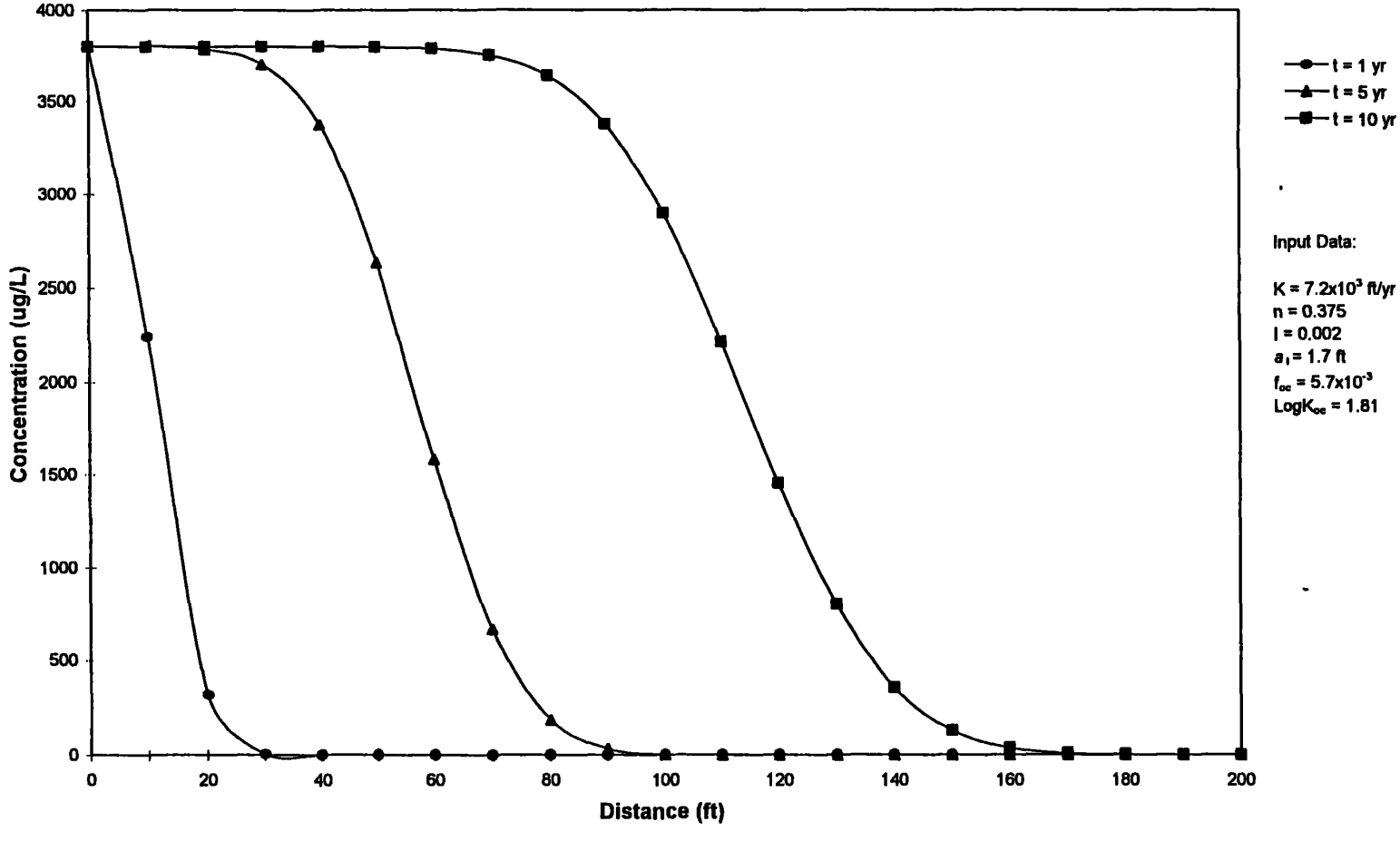
c:\jrh\socav\118-02nc.no

Breakthrough Curve
(Benzene - North)



c:\jrh\socav\118-03nc.no

Breakthrough Curve
(Benzene - North)



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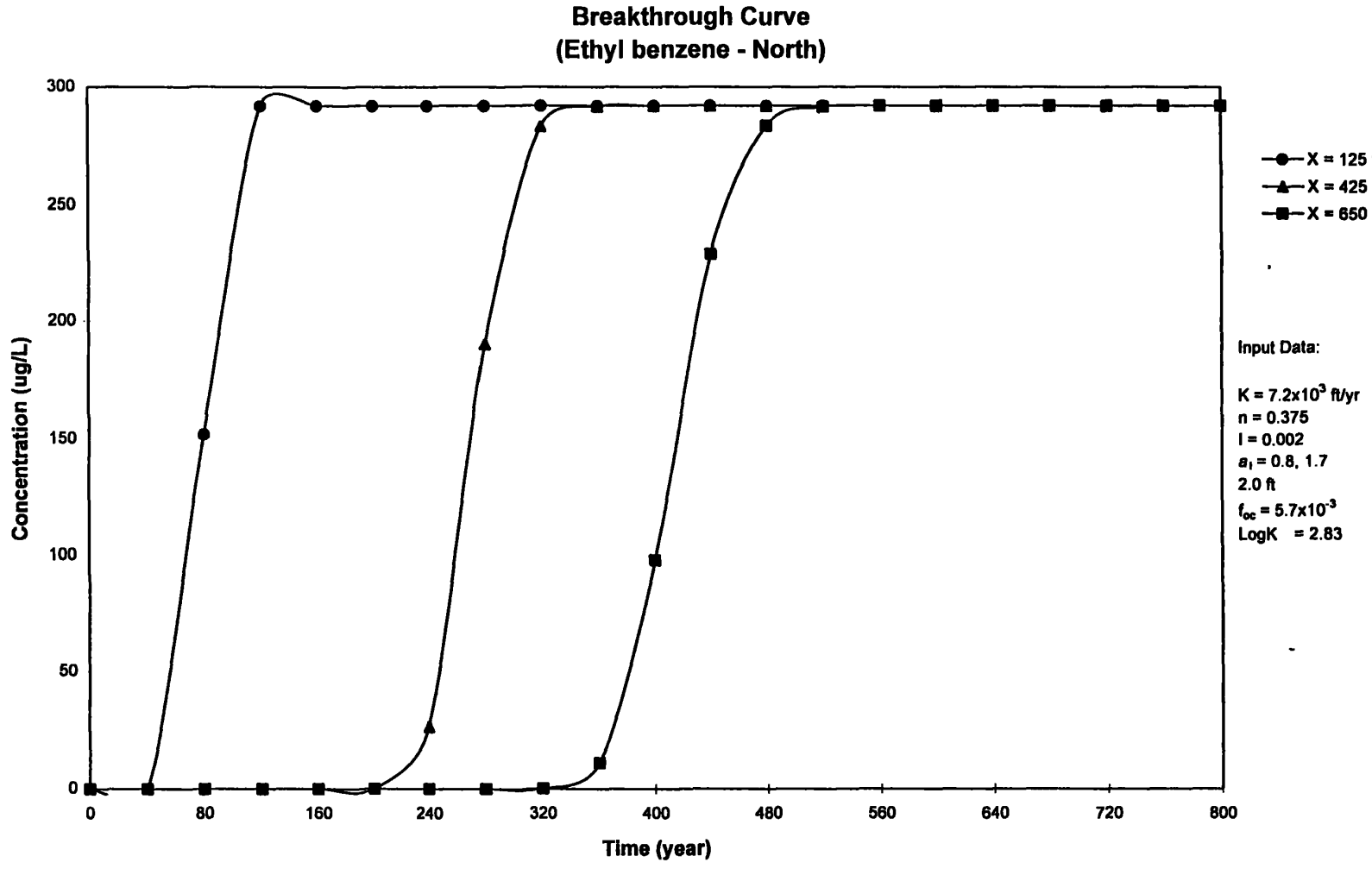
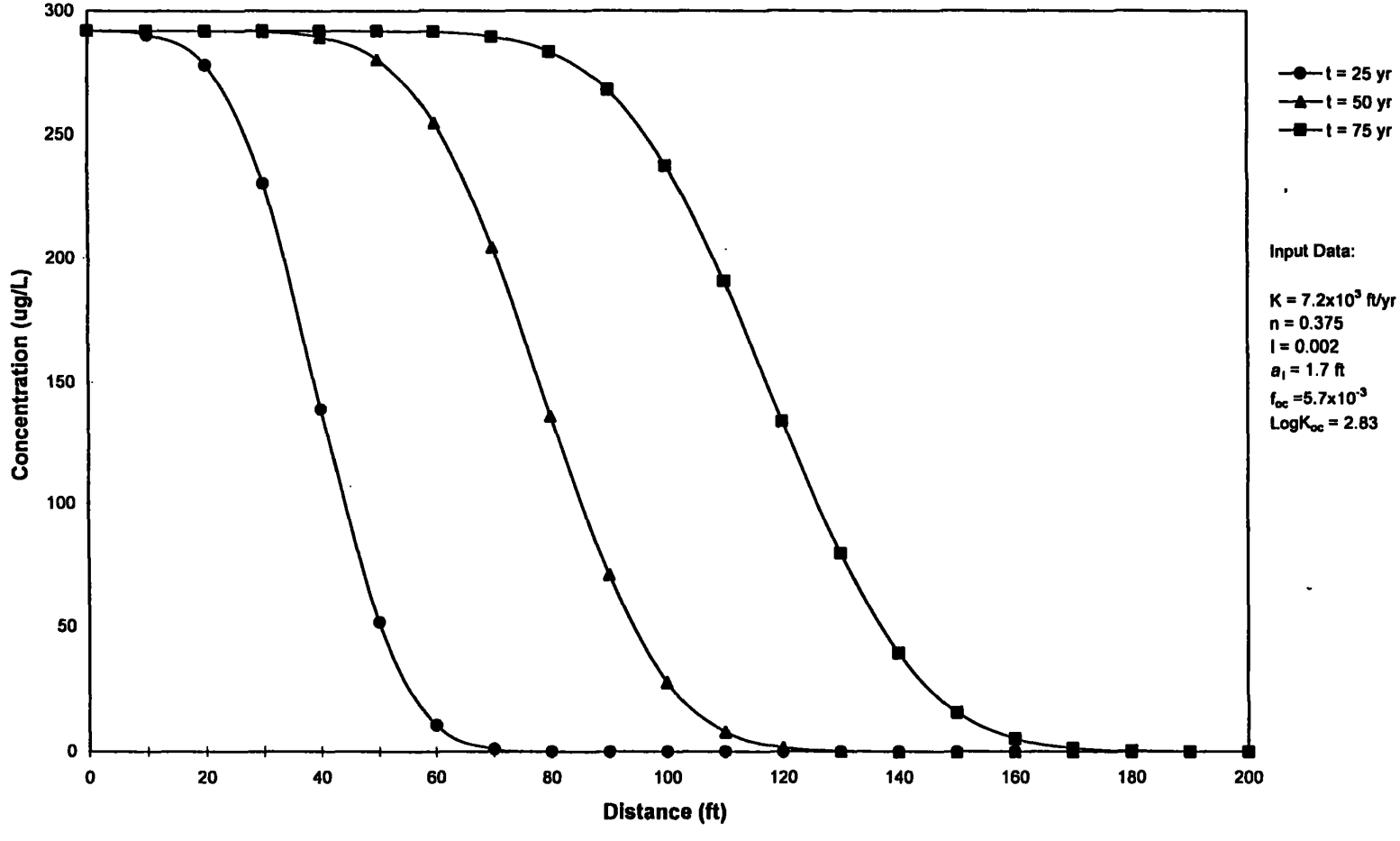


c:\jrh\socav\118-08nc.no

Breakthrough Curve
(Ethyl benzene - North)



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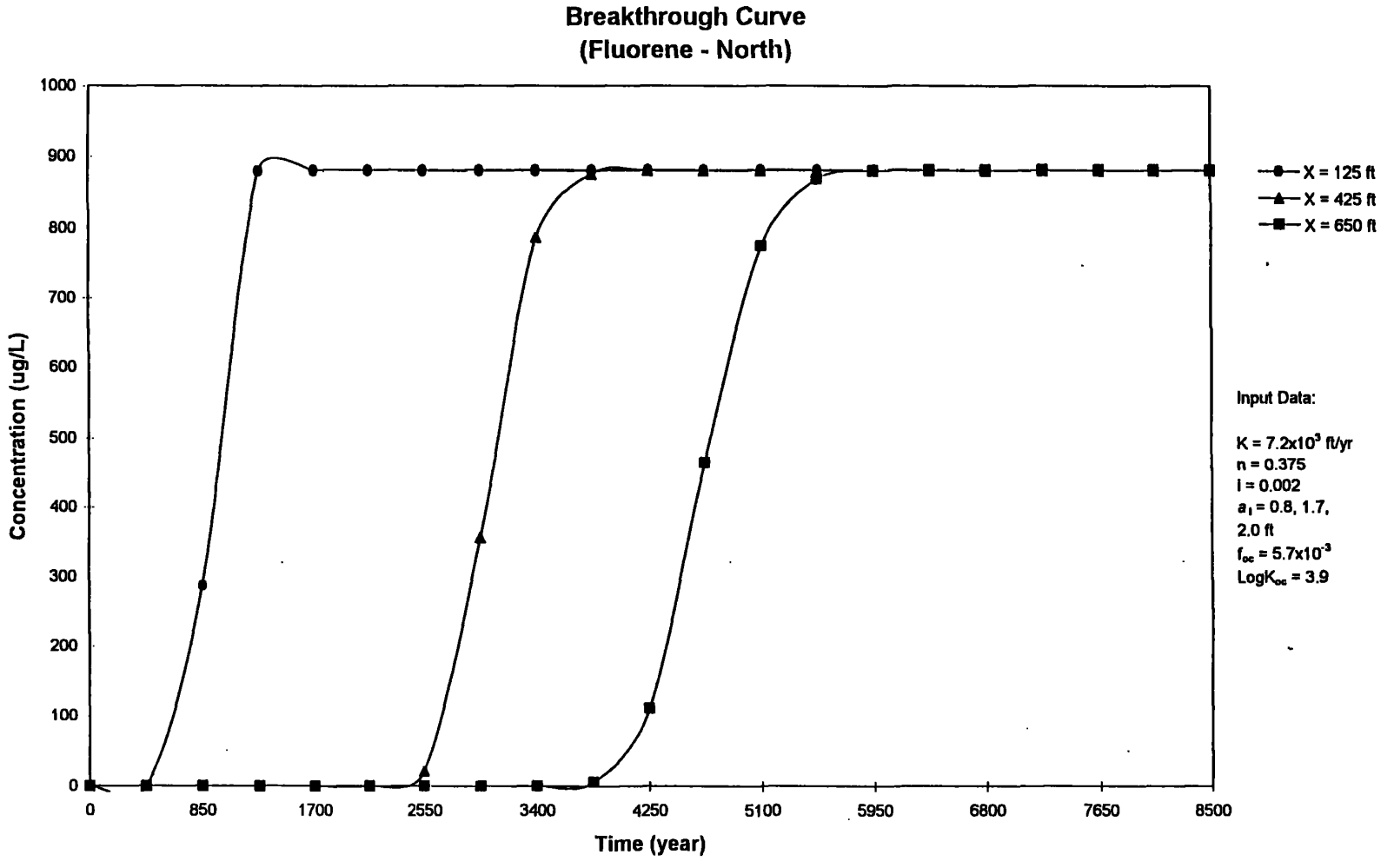
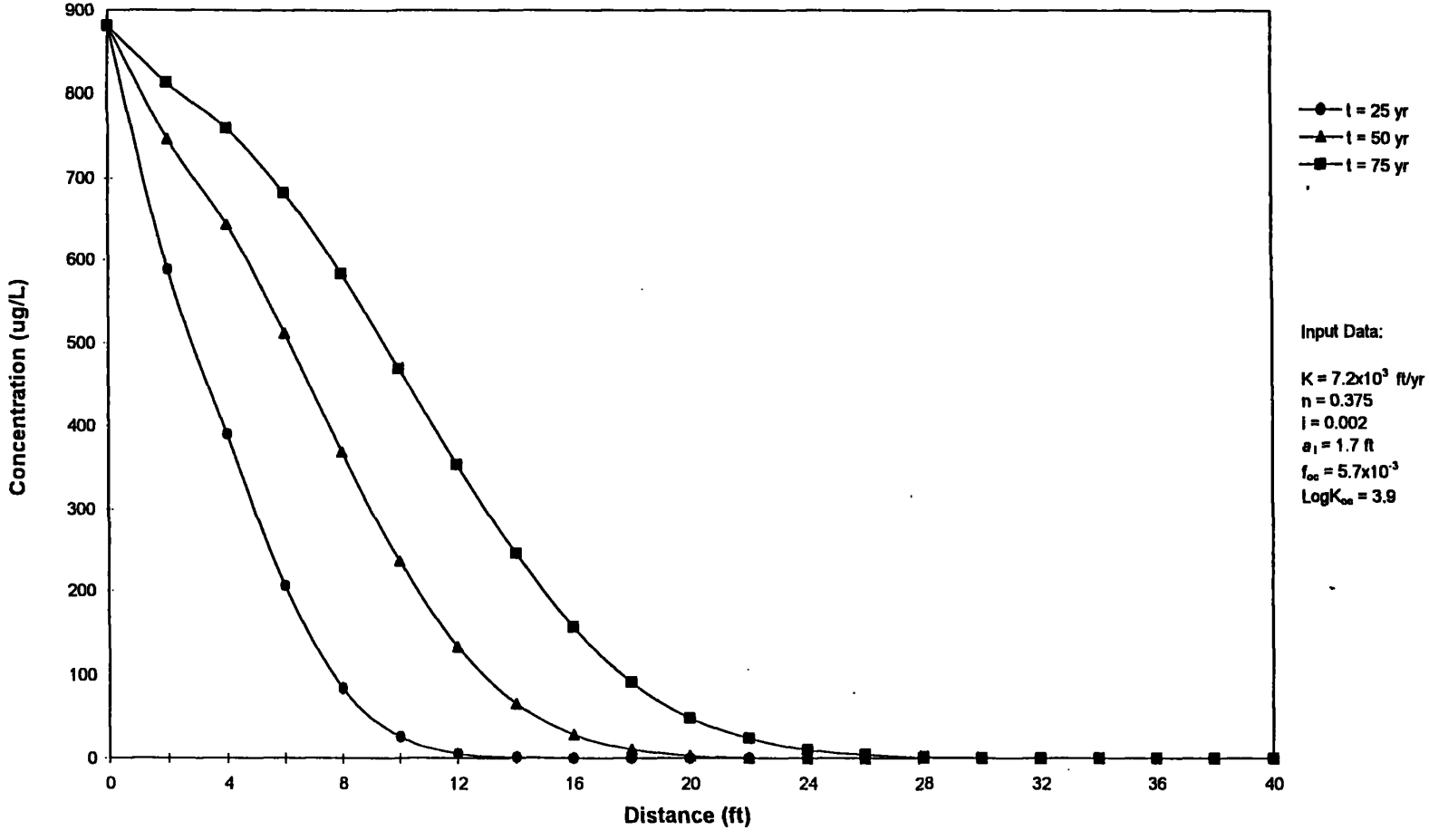


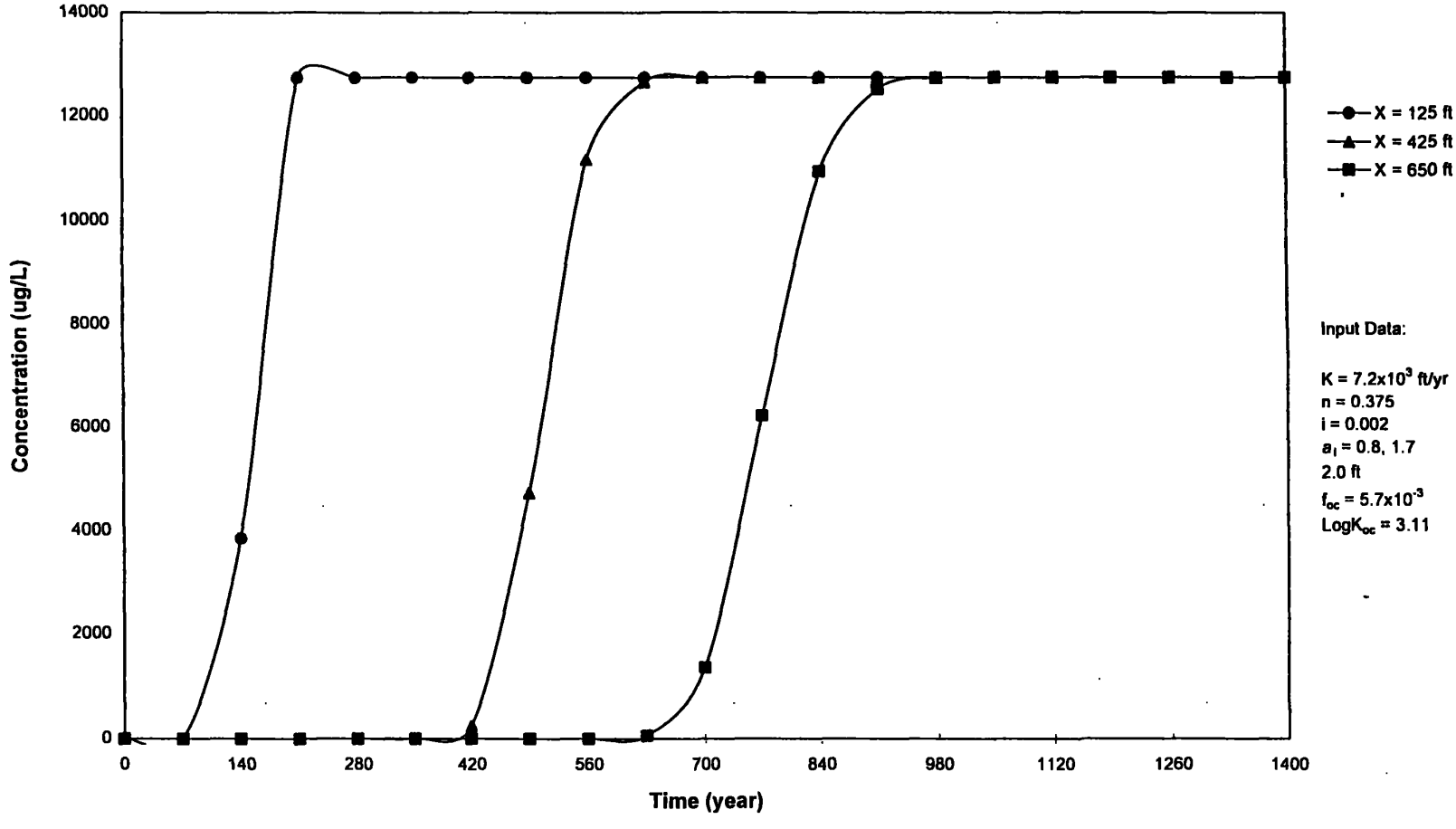
c:\jrh\socav\118-10nc.no

Breakthrough Curve
(Fluorene - North)



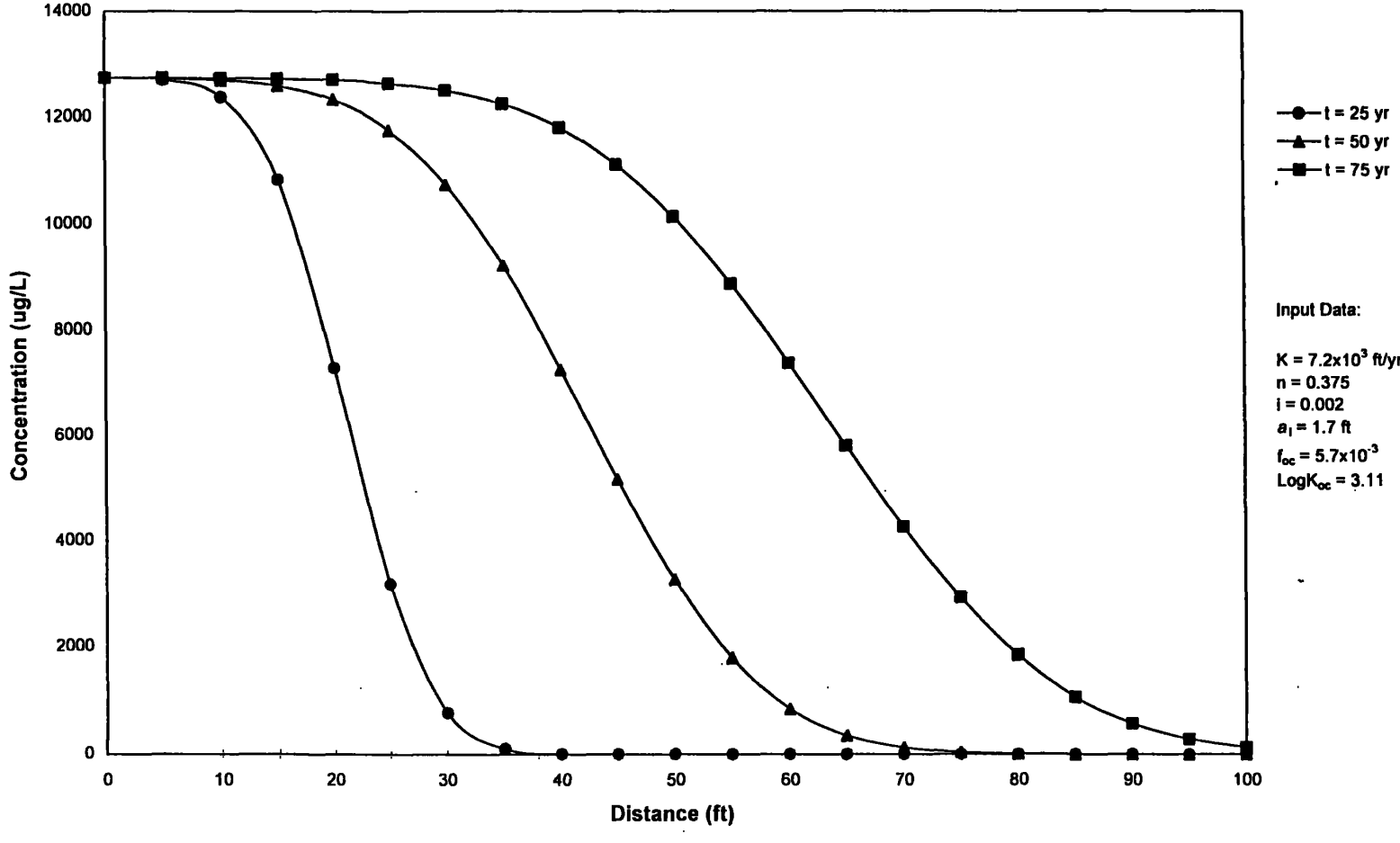
c:\jrh\socav\118-10nc.no

Breakthrough Curve
(Naphthalene - North)



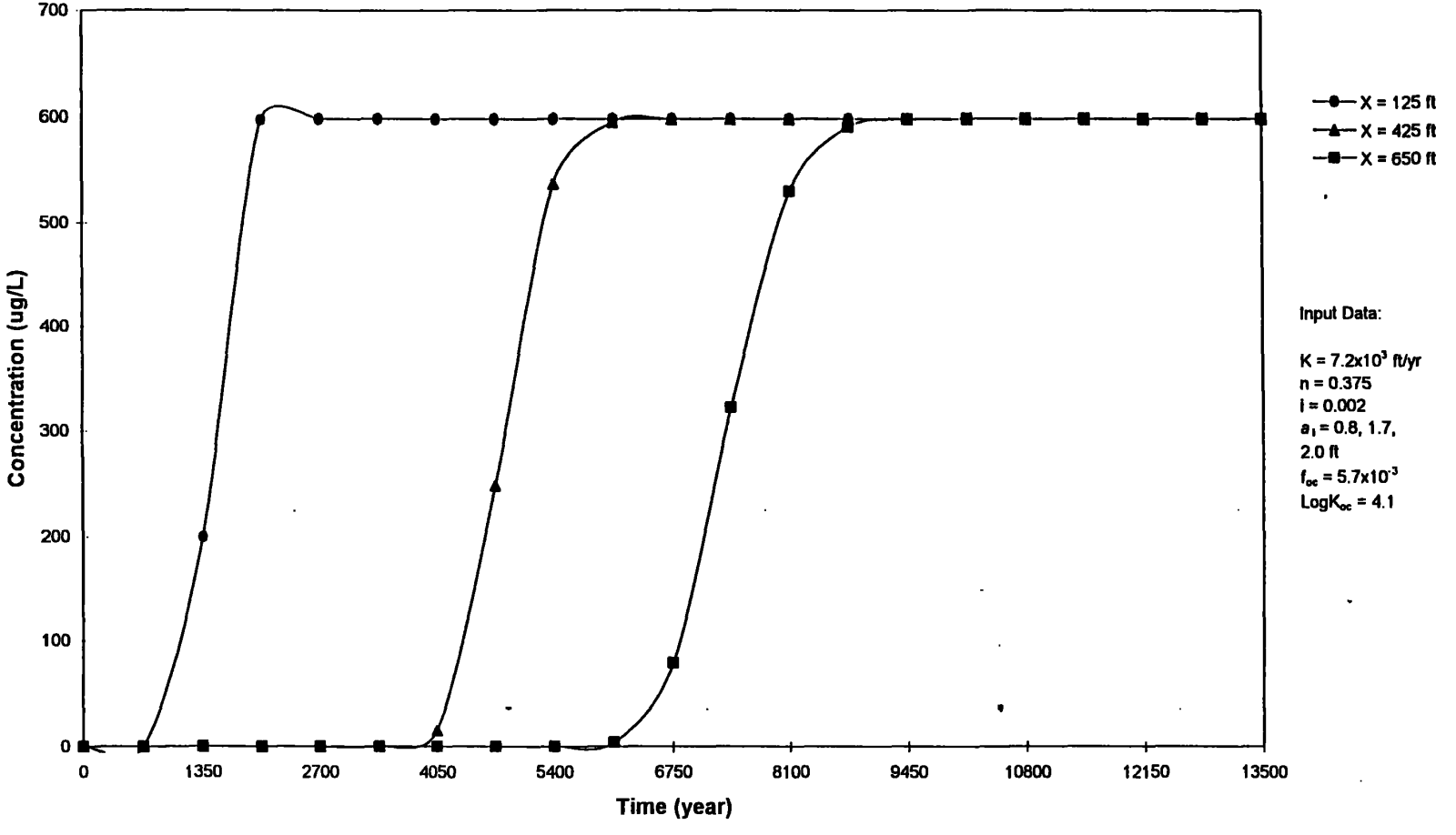
c:\jrh\socav\118-11nc.no

Breakthrough Curve
(Naphthalene - North)



c:\jrh\socav\118-11nc.no

Breakthrough Curve
(Phenanthrene - North)



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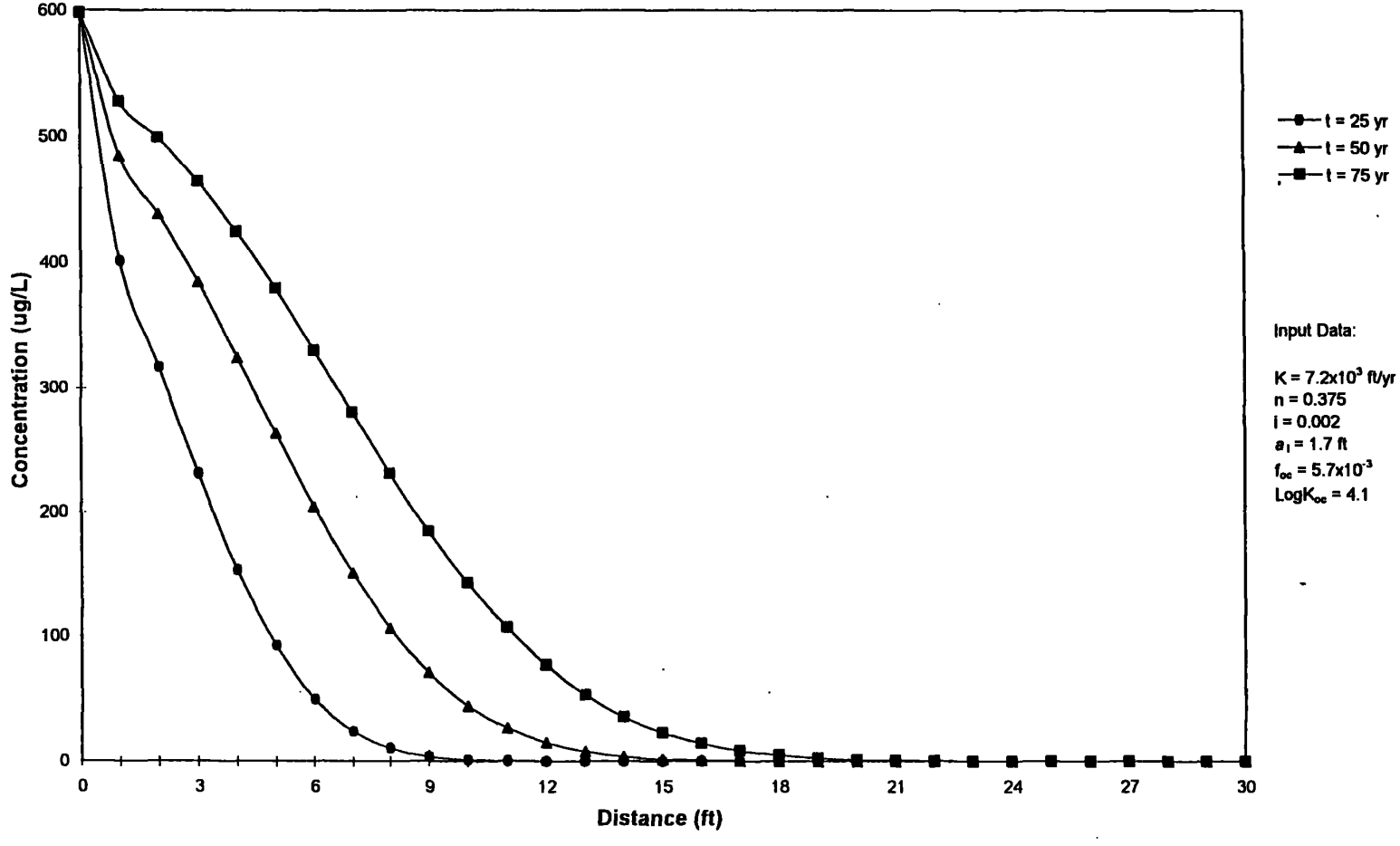
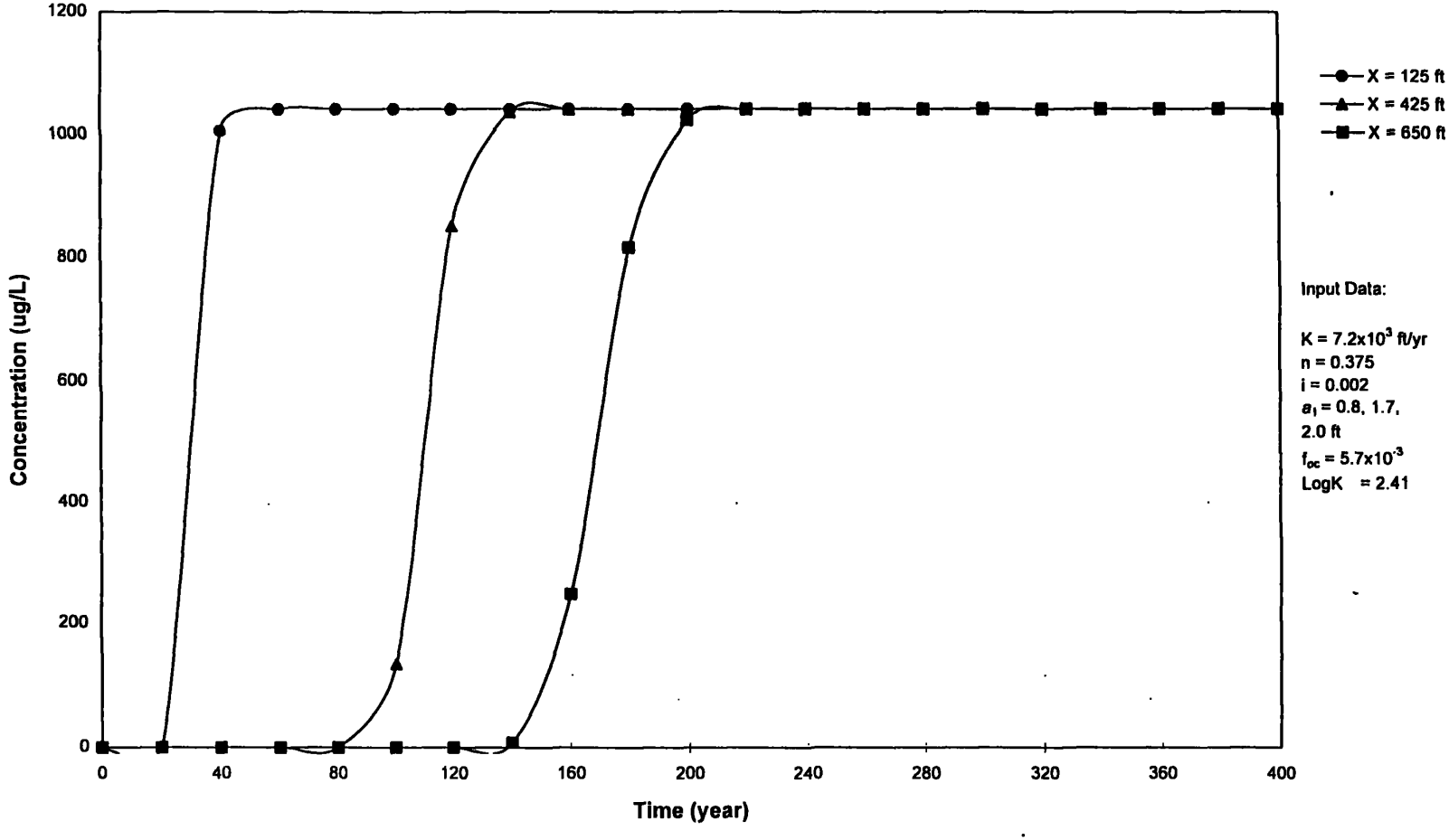
Breakthrough Curve
(Phenanthrene - North)



c:\jrh\socav\118-12nc.no

Breakthrough Curve
(Toluene - North)



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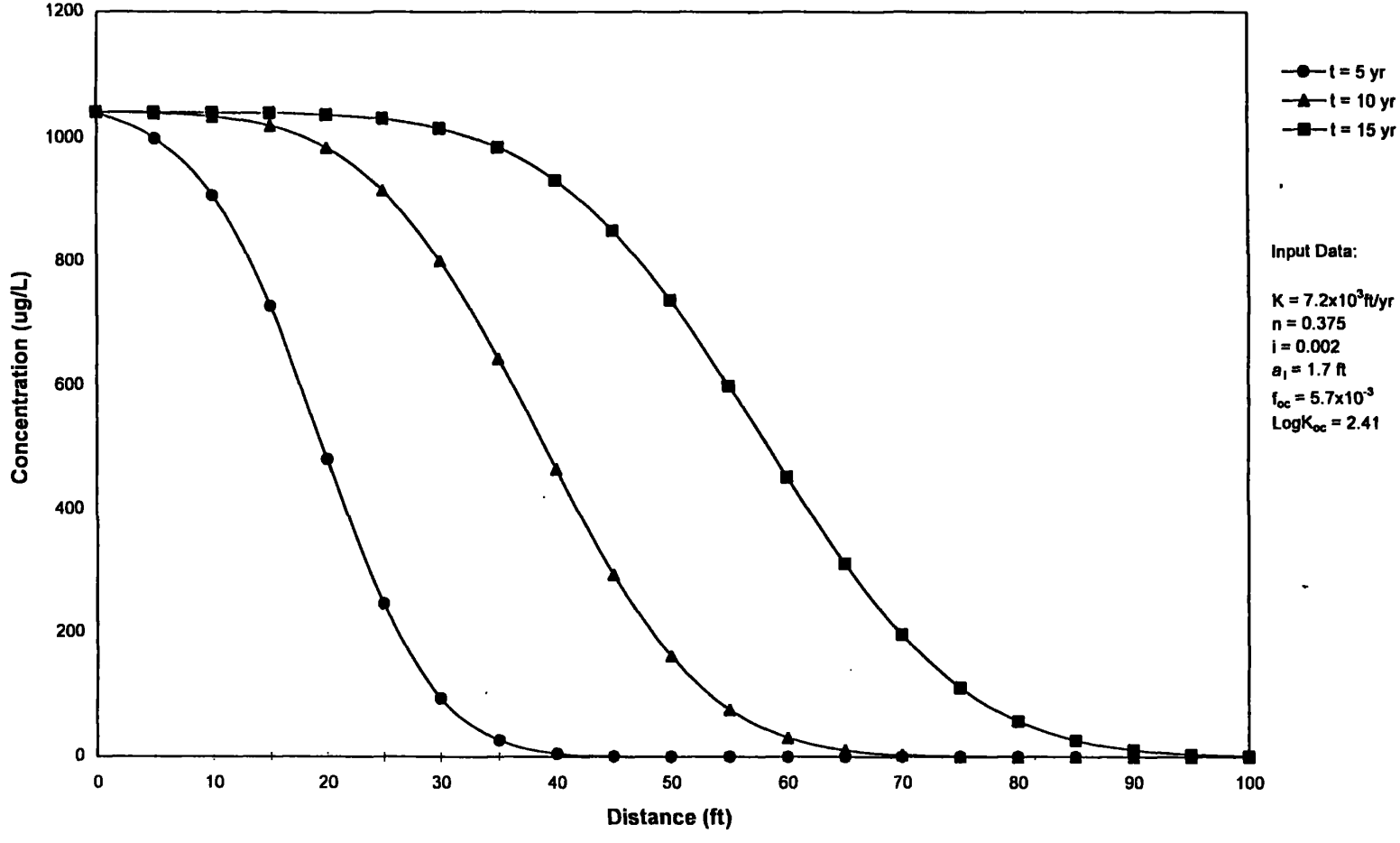
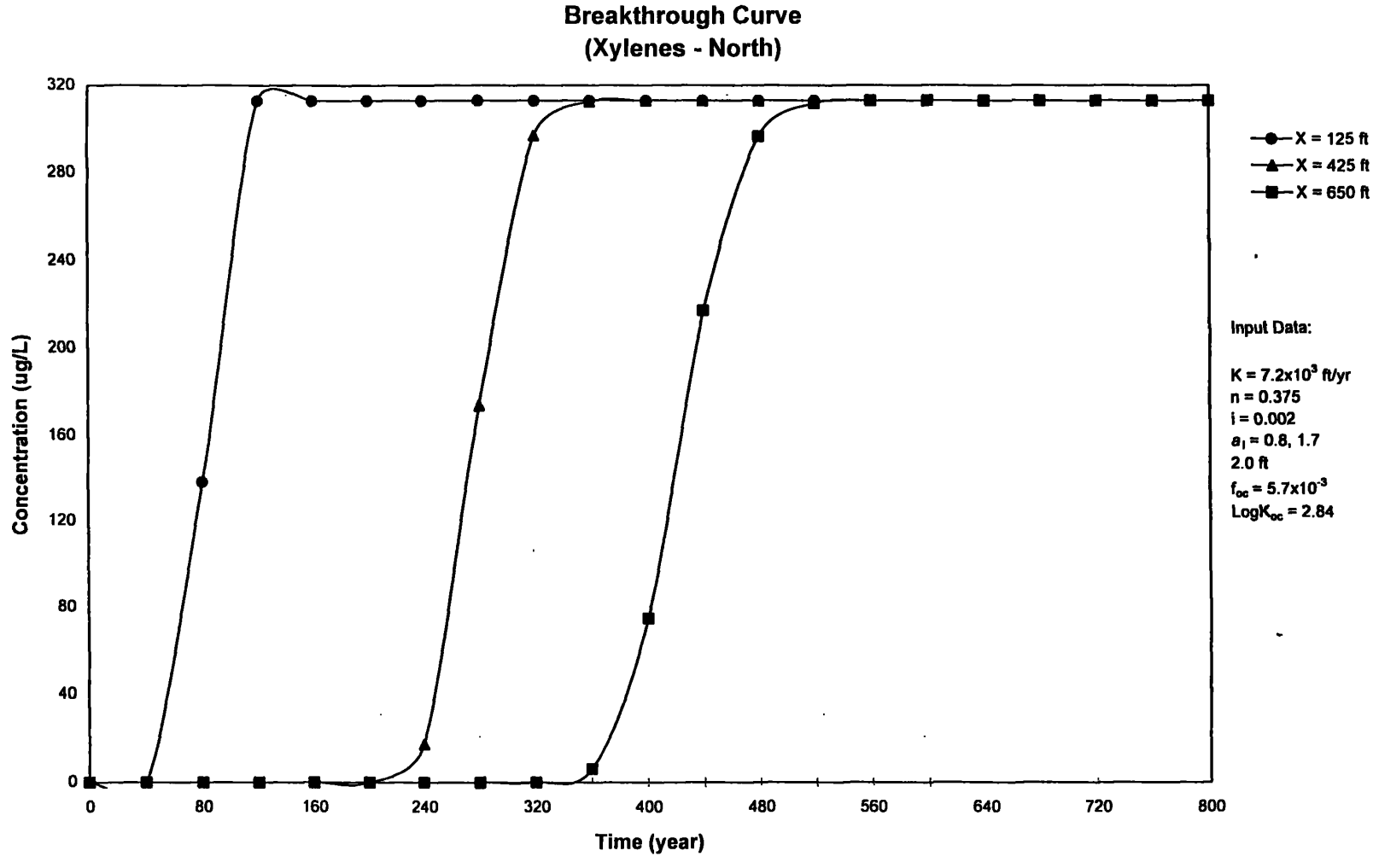
Breakthrough Curve
(Toluene - North)

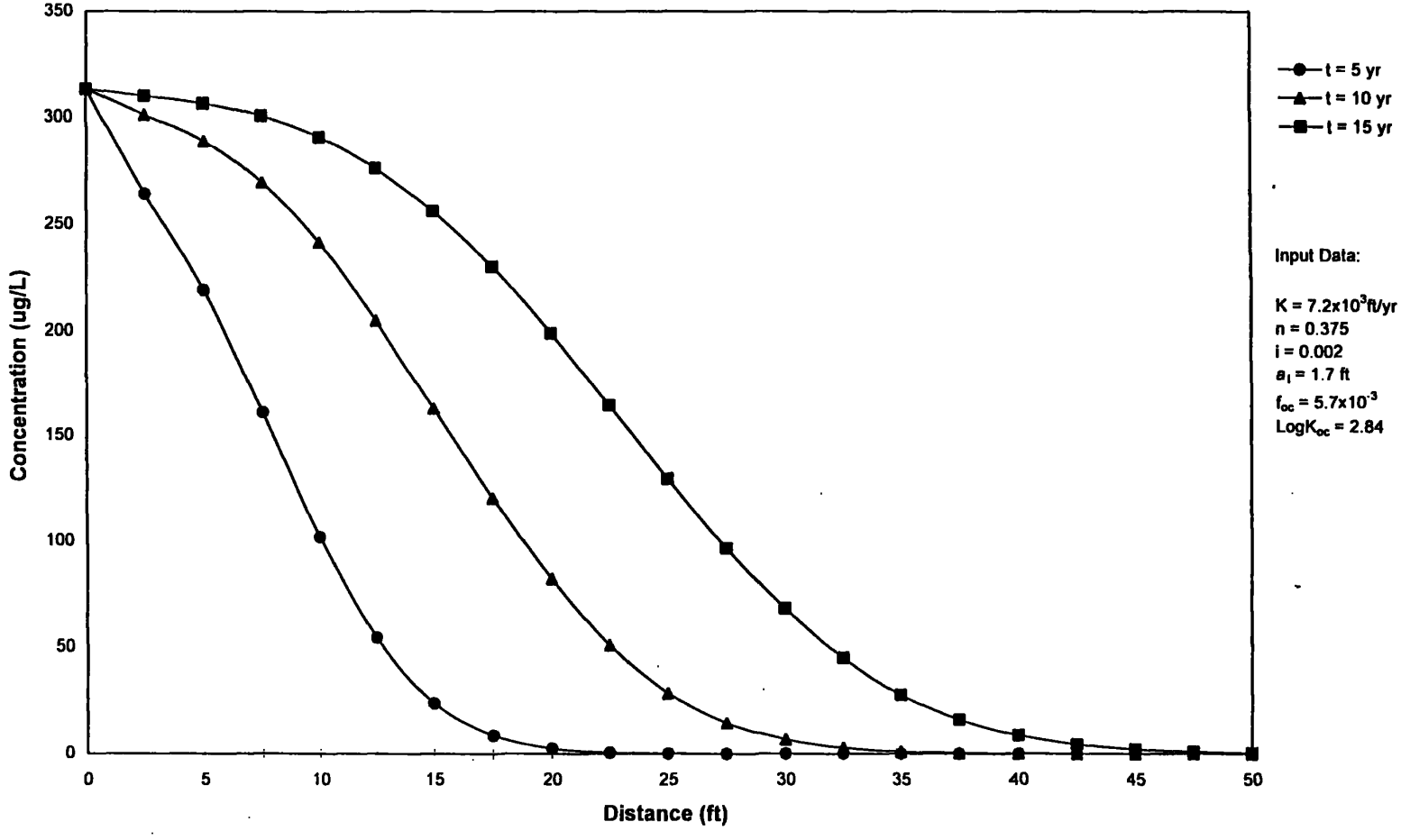


c:\jrh\socav\118-14nc.no



c:\jrh\socav\118-15nc.no

Breakthrough Curve
(Xylenes - North)



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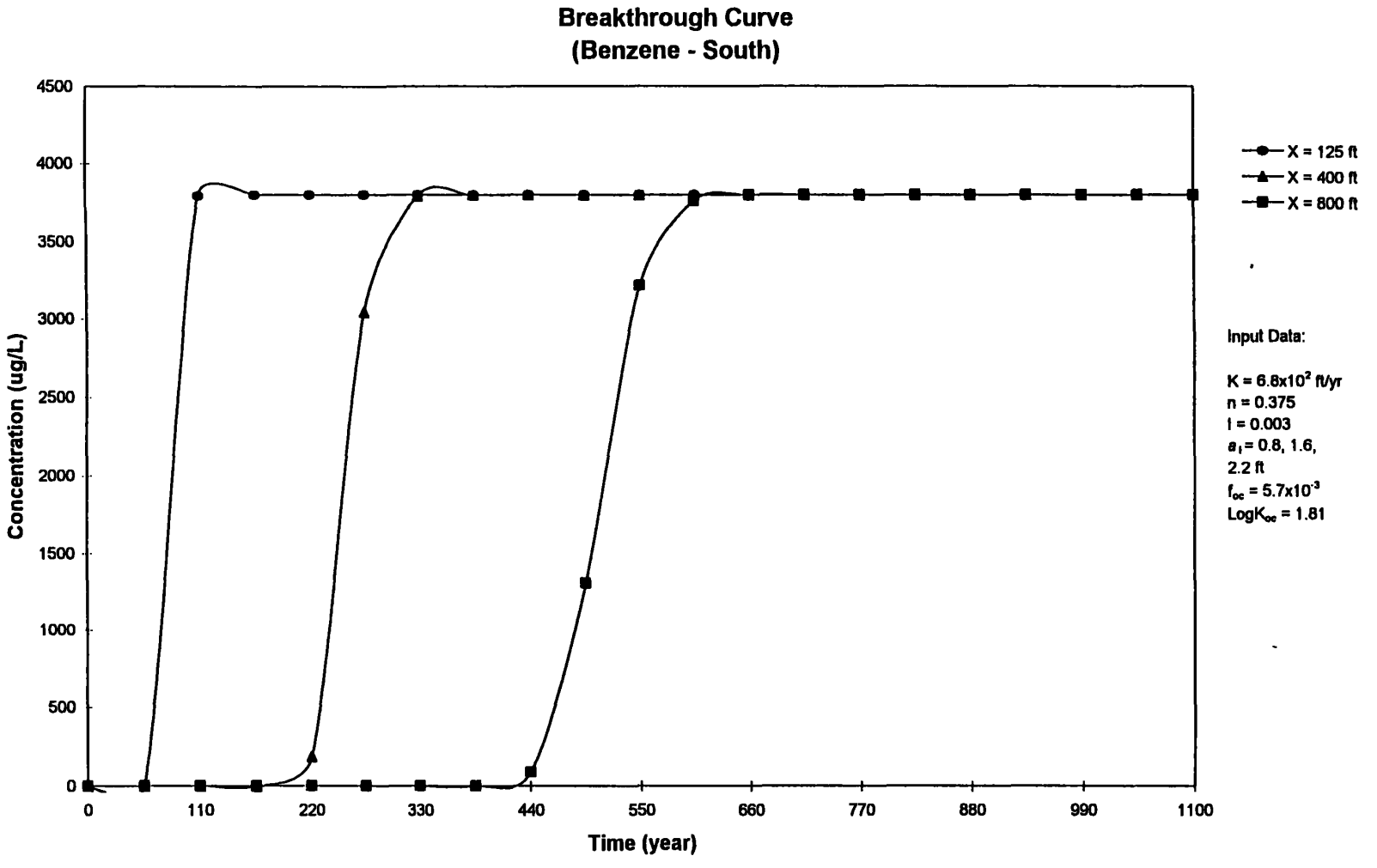
APPENDIX H

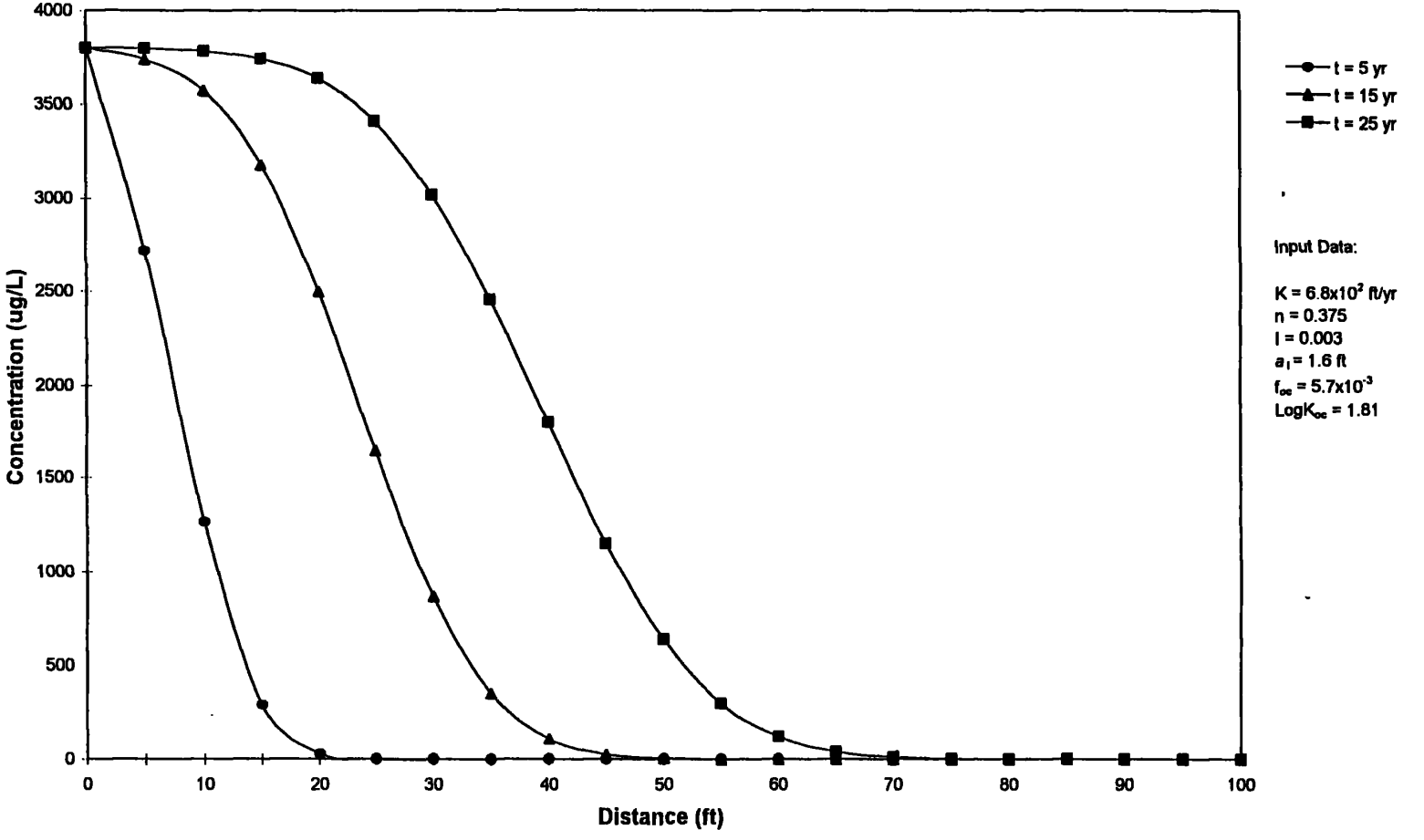
SCENARIO 3 - BEST CASE SIMULATIONS (SOUTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED

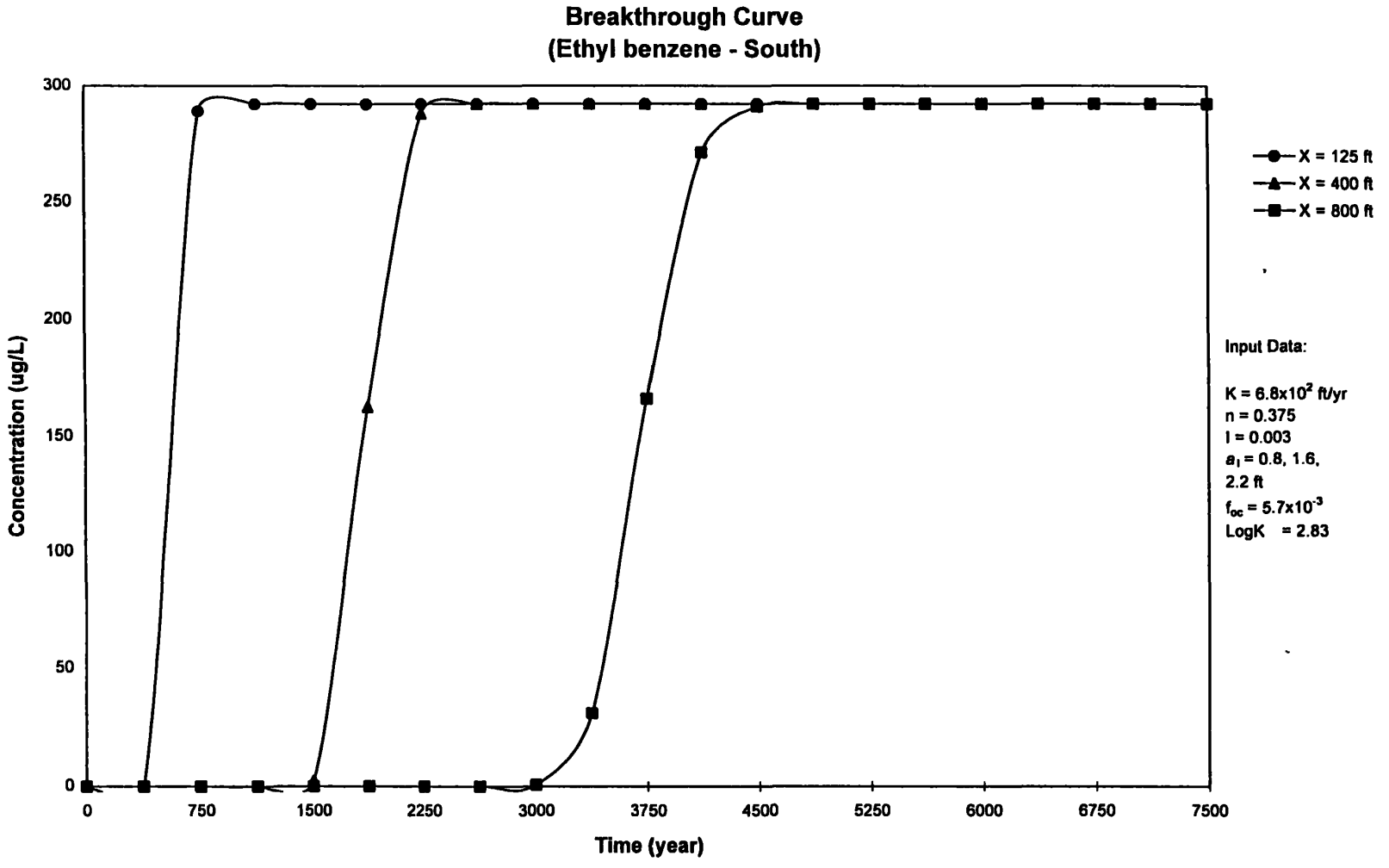


c:\jrh\socav\118-03nc.so

Breakthrough Curve
(Benzene - South)

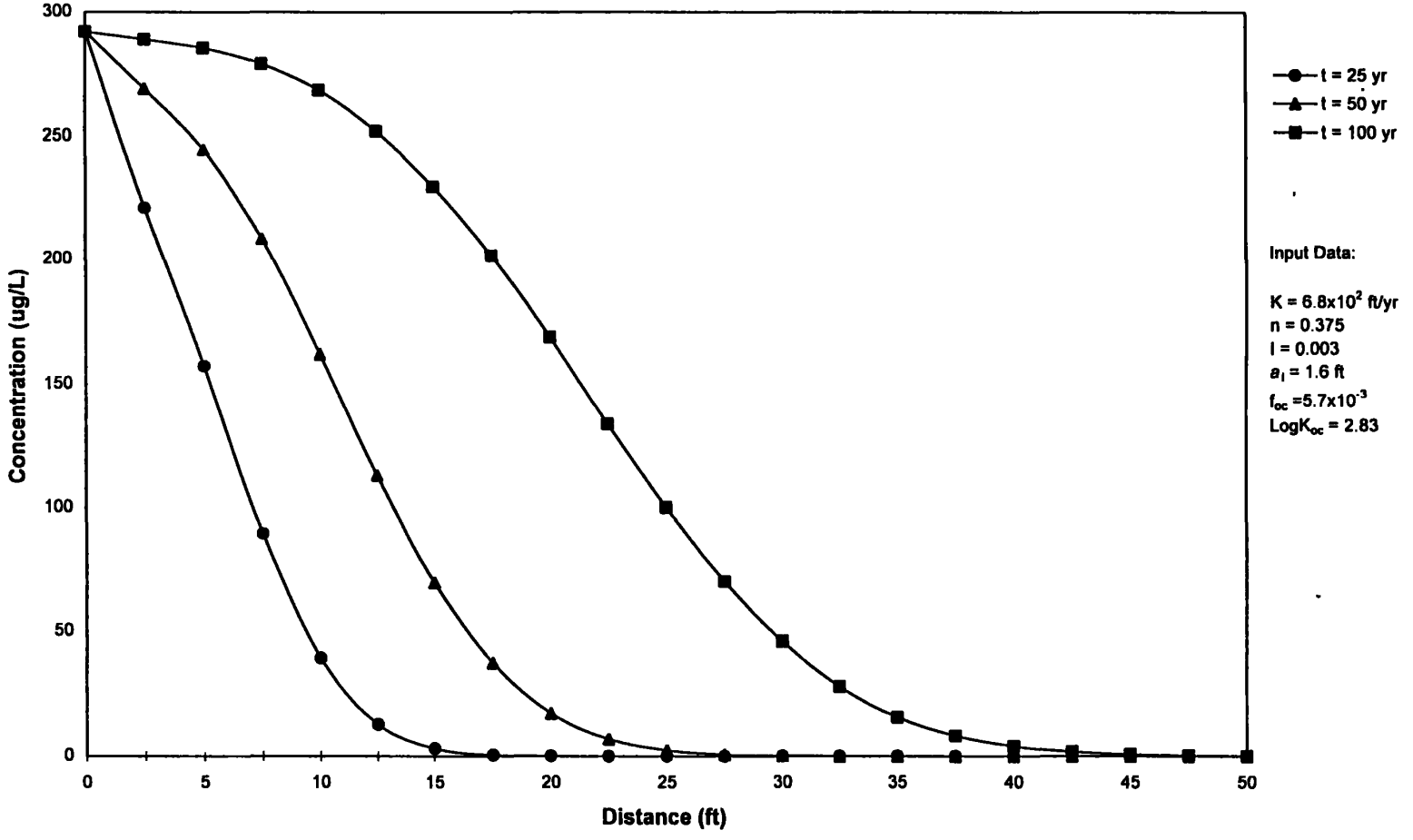


c:\jrh\socav\118-03nc.so

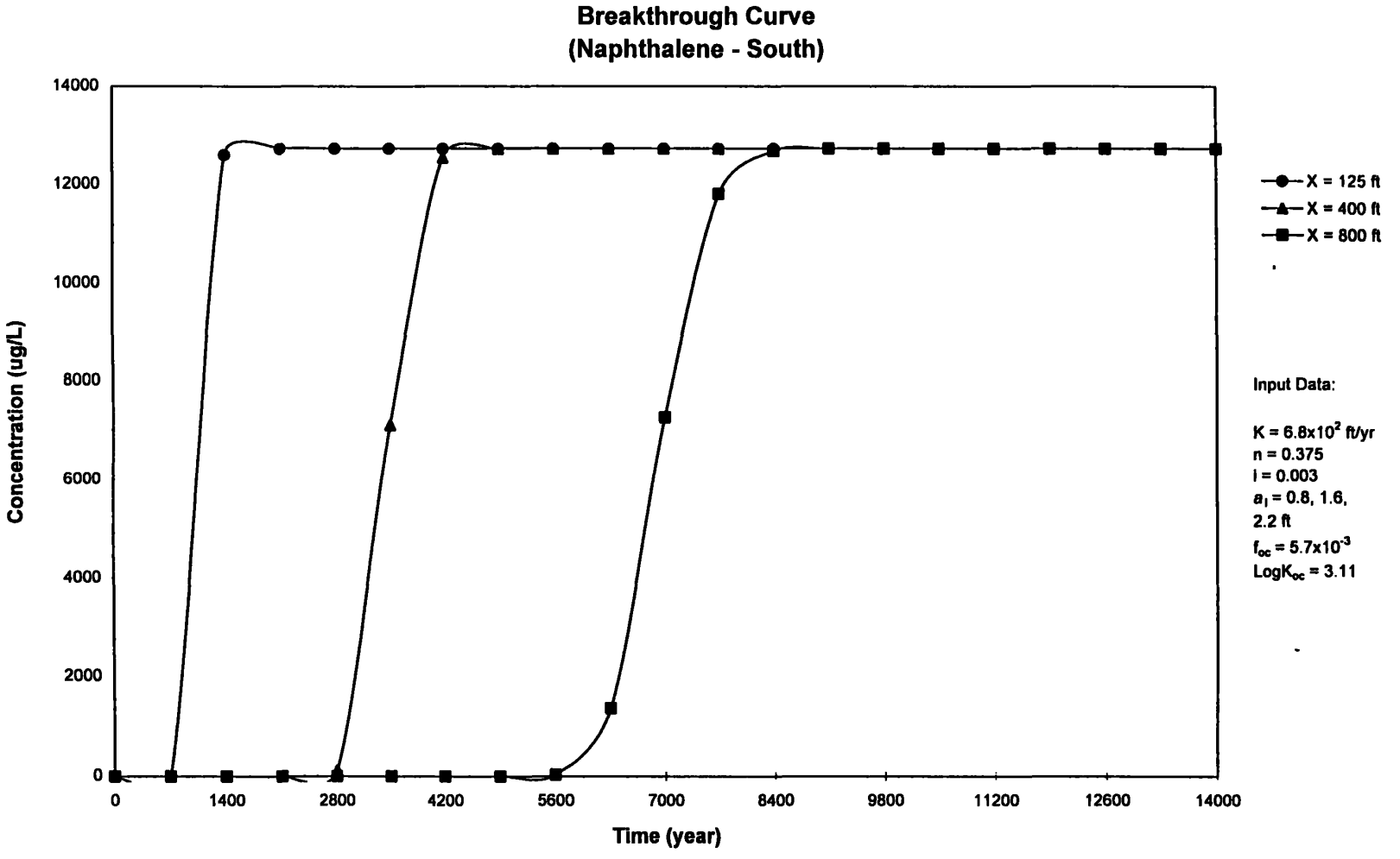


c:\jrh\socav\118-08nc.so

Breakthrough Curve
(Ethyl benzene - South)

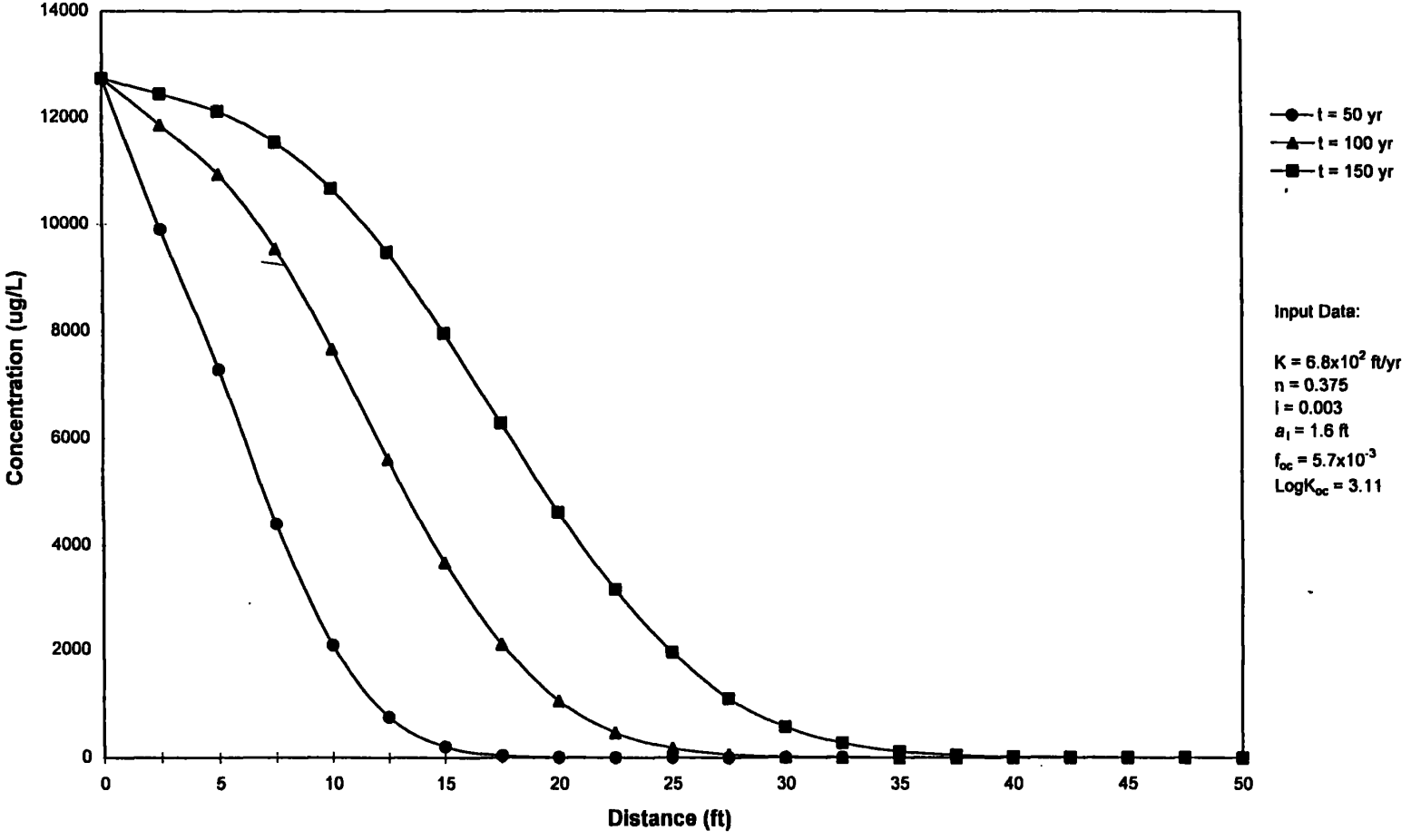


c:\jrh\socav\118-08nc.so



c:\jrh\socav\118-11nc.so

Breakthrough Curve
(Naphthalene - South)



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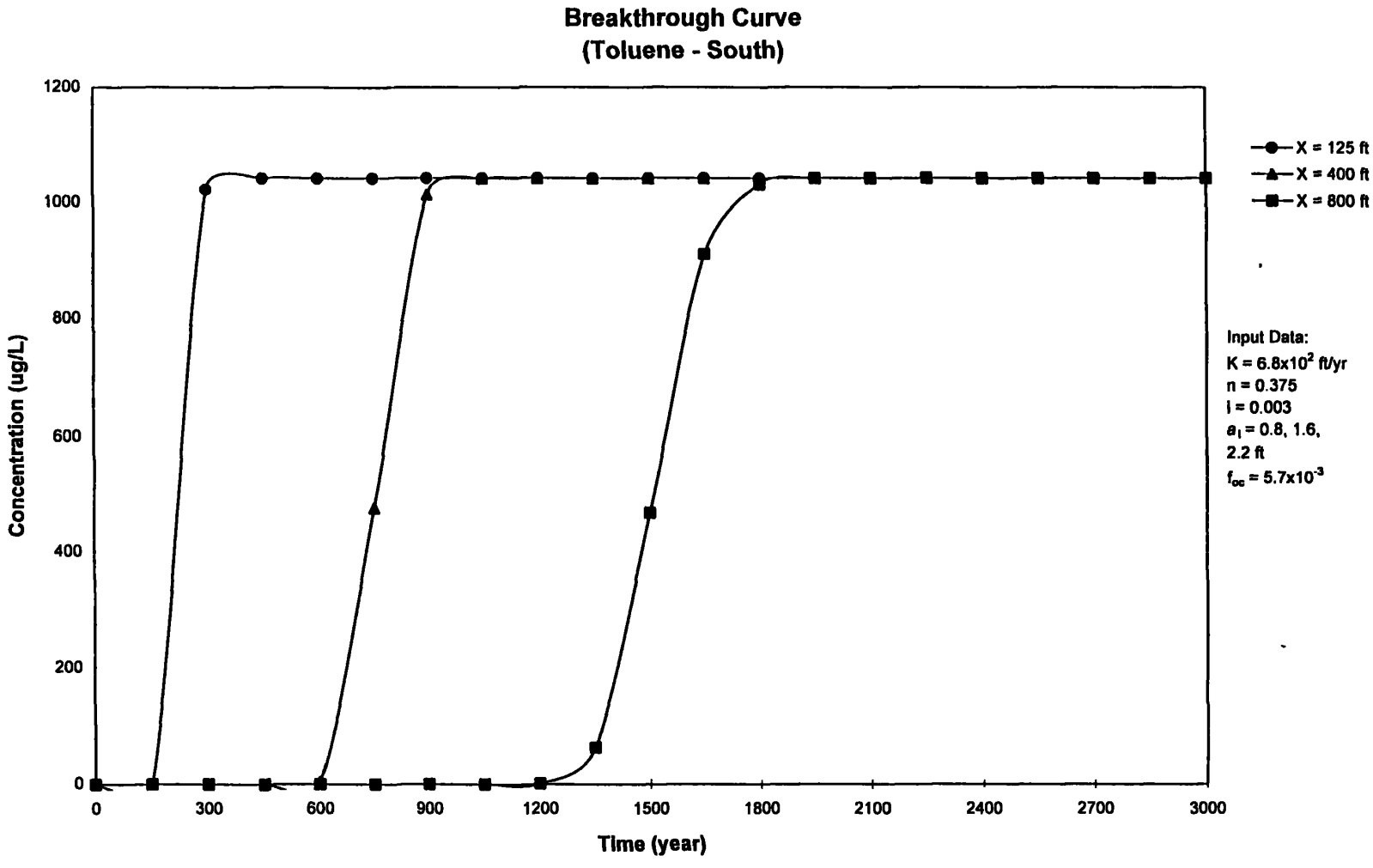
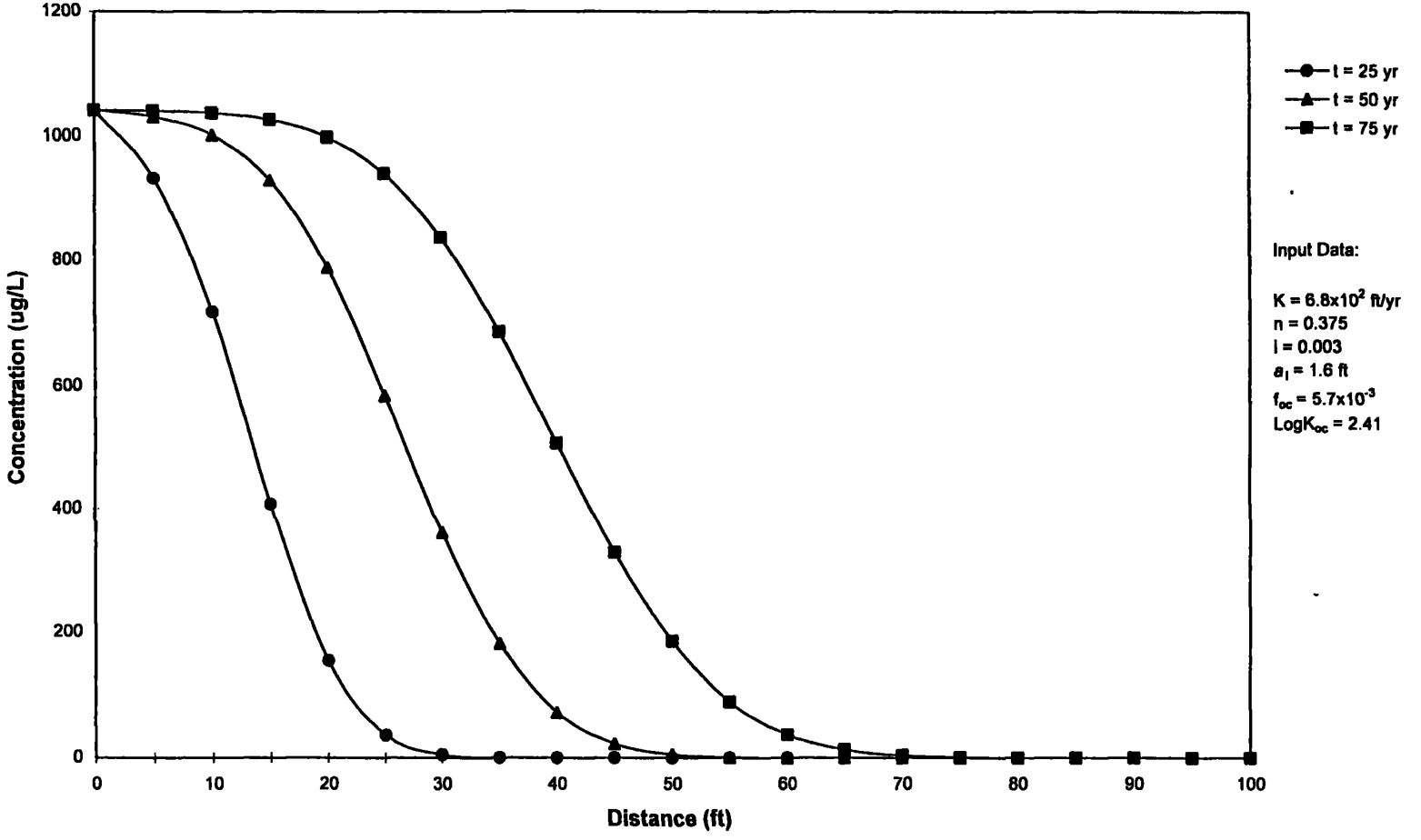
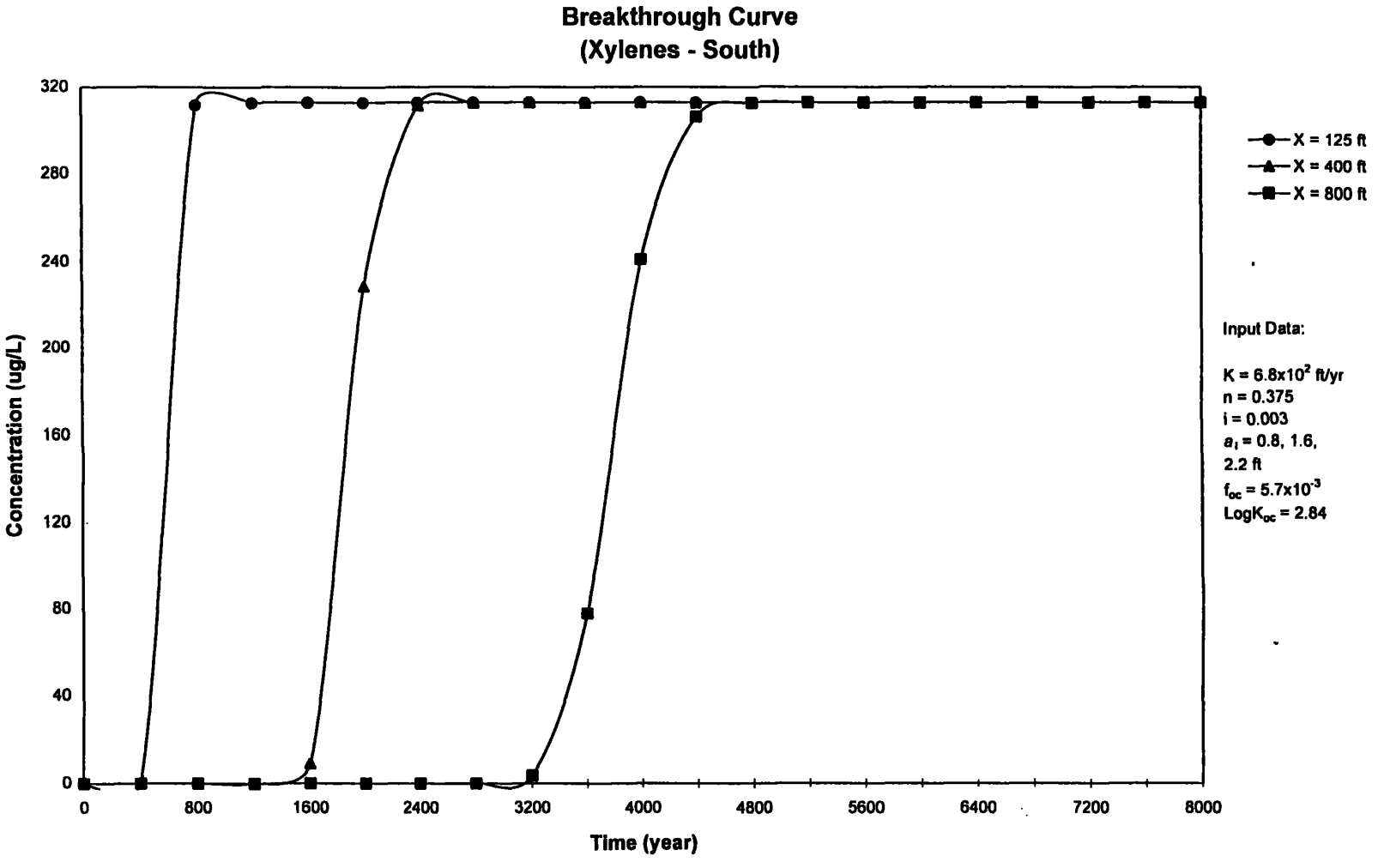


c:\jrh\socav\118-14nc.so

Breakthrough Curve
(Toluene - South)

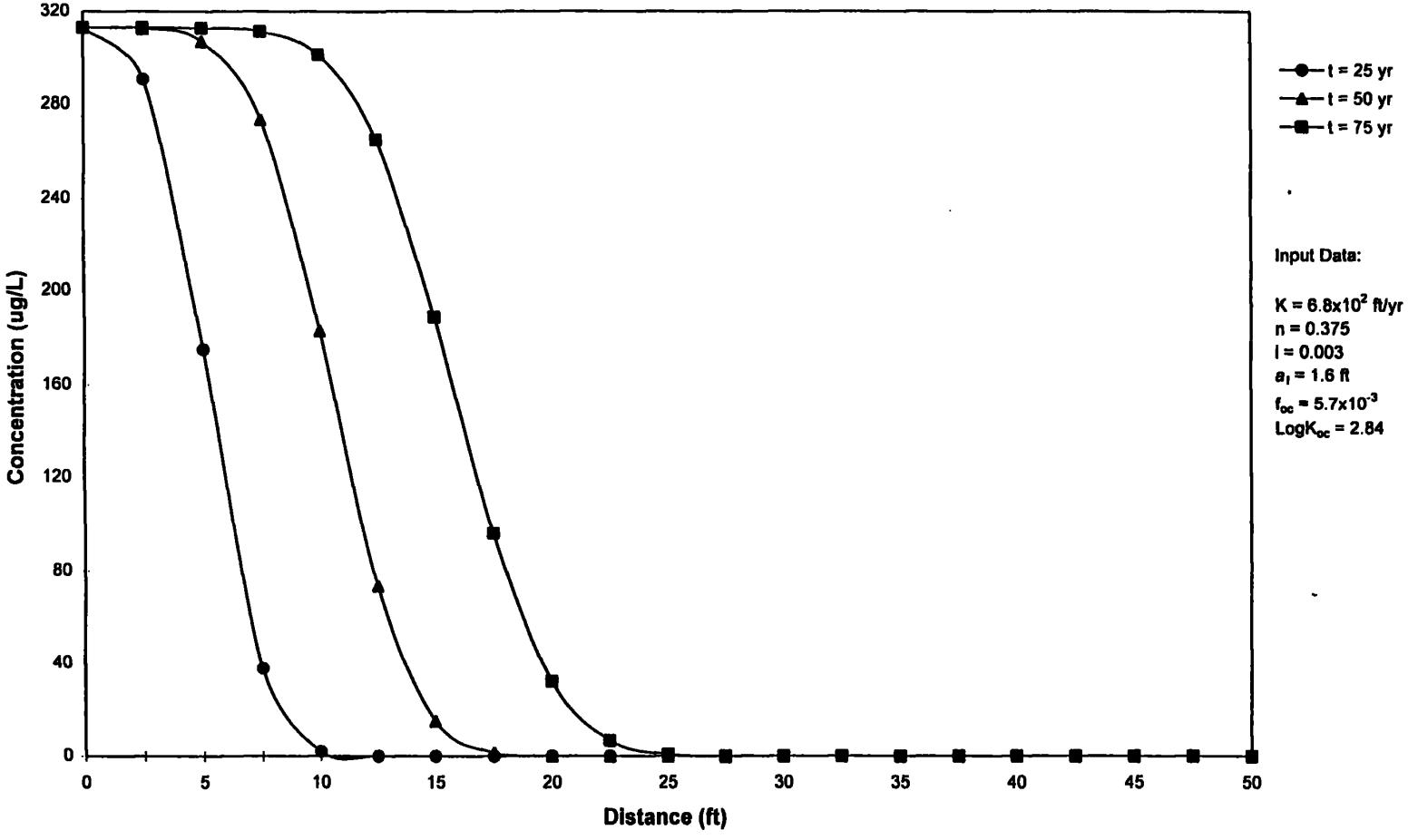


c:\jrh\socav\118-14nc.so



c:\jrh\socav\118-15nc.so

Breakthrough Curve
(Xylenes - South)



c:\jrh\socav\118-15nc.so

APPENDIX I

SCENARIO 4 - BIOSCREEN SIMULATIONS (NORTHERN AREA)

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Acenaphthene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

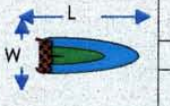
Retardation Factor*	R	16.2	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	5010	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.2E+0	(per yr)
or		or	
Solute Half-Life	t-half	0.56	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	6	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

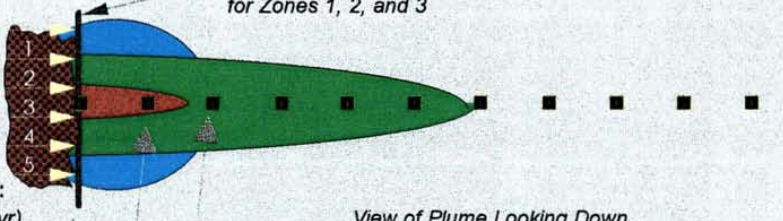
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	1.785
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.065				
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

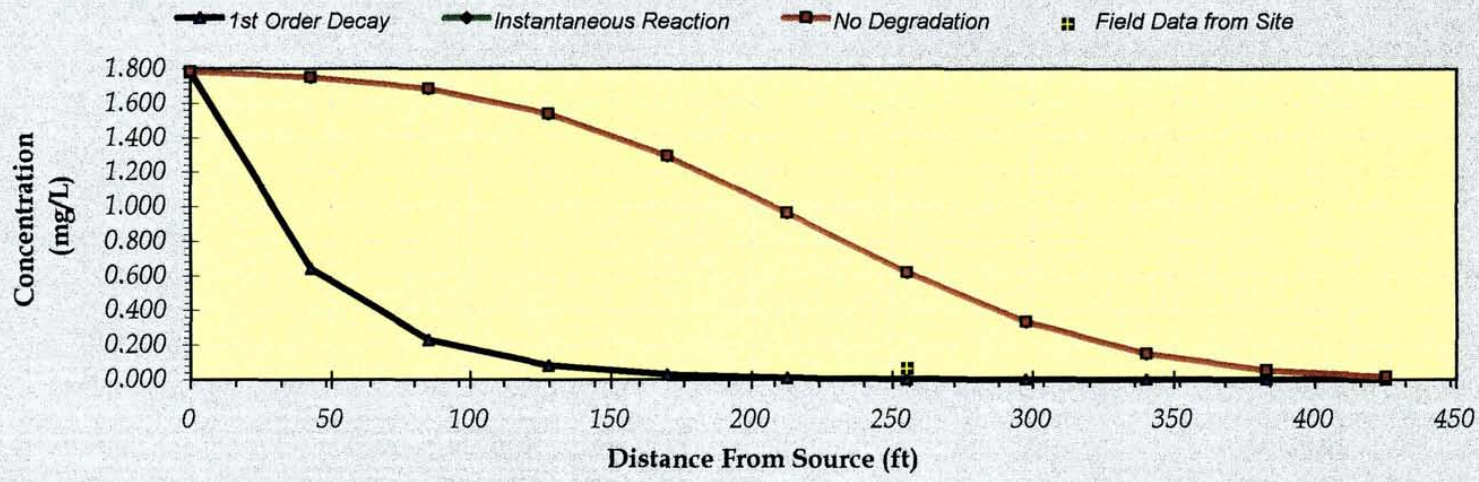
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ACENAPHTHENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

TYPE OF MODEL	Distance from Source (ft) 0	43	85	128	170	213	255	298	340	383	425
No Degradation	1.785	1.752	1.685	1.541	1.294	0.965	0.619	0.333	0.147	0.053	0.015
1st Order Decay	1.785	0.643	0.232	0.083	0.030	0.011	0.004	0.001	0.000	0.000	0.000
Inst. Reaction	1.785	1.752	1.685	1.541	1.294	0.965	0.619	0.333	0.147	0.053	0.015
Field Data from Site							0.065				



Calculate Animation

Time: 6.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Anthracene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

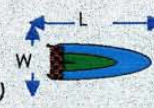
Retardation Factor*	R	39.3	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	12600	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	2.8E-1	(per yr)
or		or	
Solute Half-Life	t-half	2.52	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	22	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

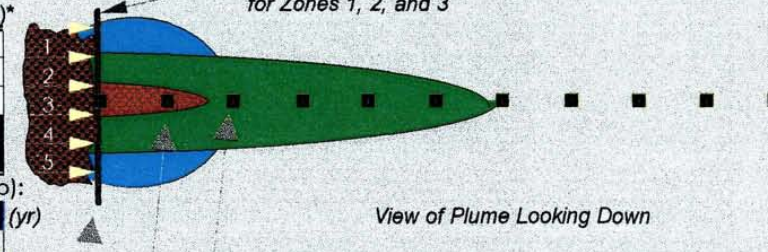
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.339
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.001
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

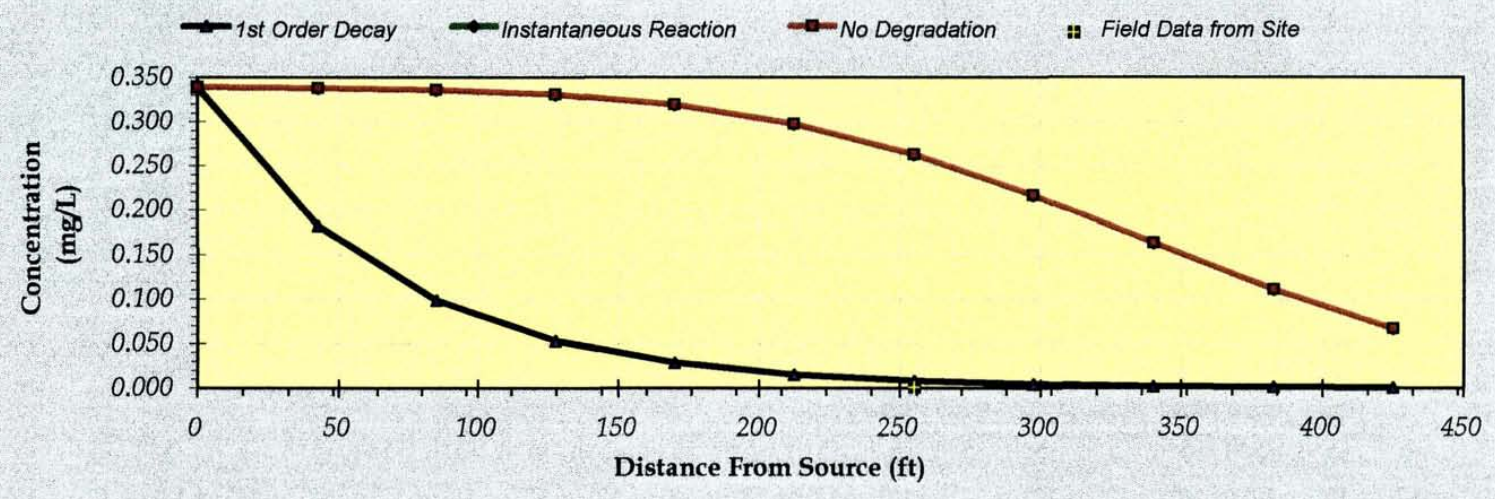
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ANTHRACENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	**0**	**43**	**85**	**128**	**170**	**213**	**255**	**298**	**340**	**383**	**425**
No Degradation	0.339	0.338	0.336	0.331	0.319	0.297	0.263	0.217	0.163	0.110	0.067
1st Order Decay	0.339	0.183	0.098	0.053	0.029	0.015	0.008	0.004	0.002	0.001	0.001
Inst. Reaction	0.339	0.338	0.336	0.331	0.319	0.297	0.263	0.217	0.163	0.110	0.067
Field Data from Site							0.001				



Calculate Animation

Time: 22.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Benzene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

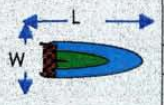
Retardation Factor*	R	1.2	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	64.6	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	3.5E-1	(per yr)
or		or	
Solute Half-Life	t-half	2.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	3	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

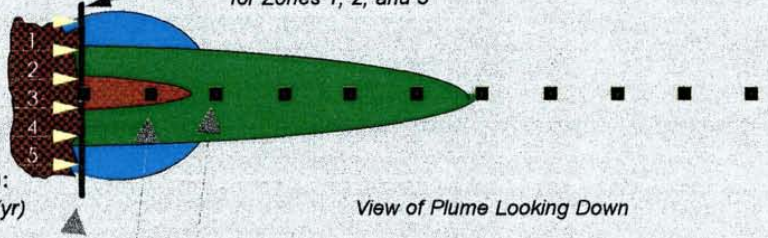
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	3.799
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.006
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

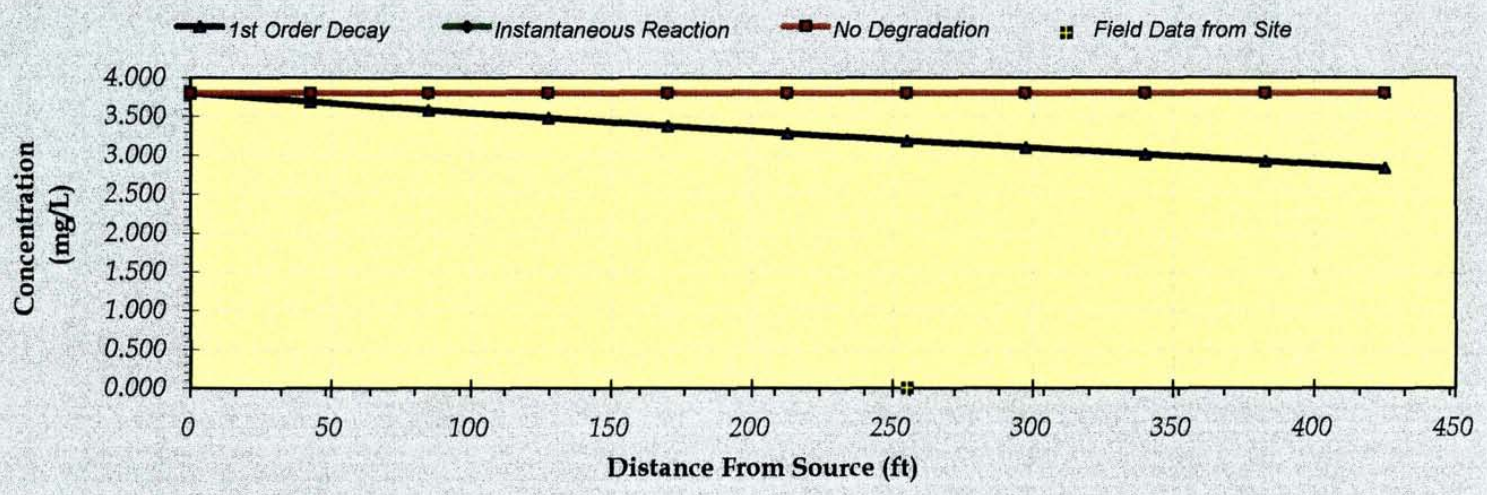
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED BENZENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799
1st Order Decay	3.799	3.690	3.584	3.481	3.381	3.284	3.190	3.098	3.009	2.923	2.839
Inst. Reaction	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799
Field Data from Site							0.006				



Calculate Animation

Time: 3.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Ethylbenzene

Data Input Instructions:

115 (or 0.02)
1. Enter value directly....or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.
20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

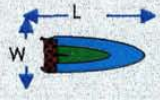
Retardation Factor*	R	3.1	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	676	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.1E+0	(per yr)
or		or	
Solute Half-Life	t-half	0.62	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	5	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

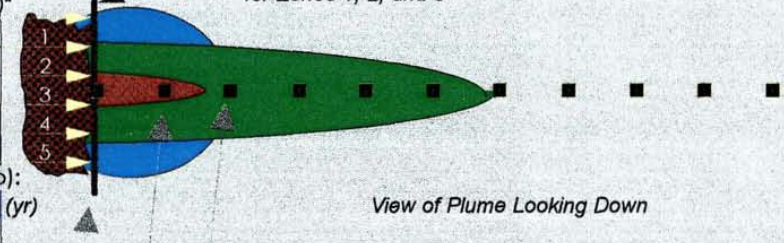
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.292
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.008
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

Recalculate This Sheet

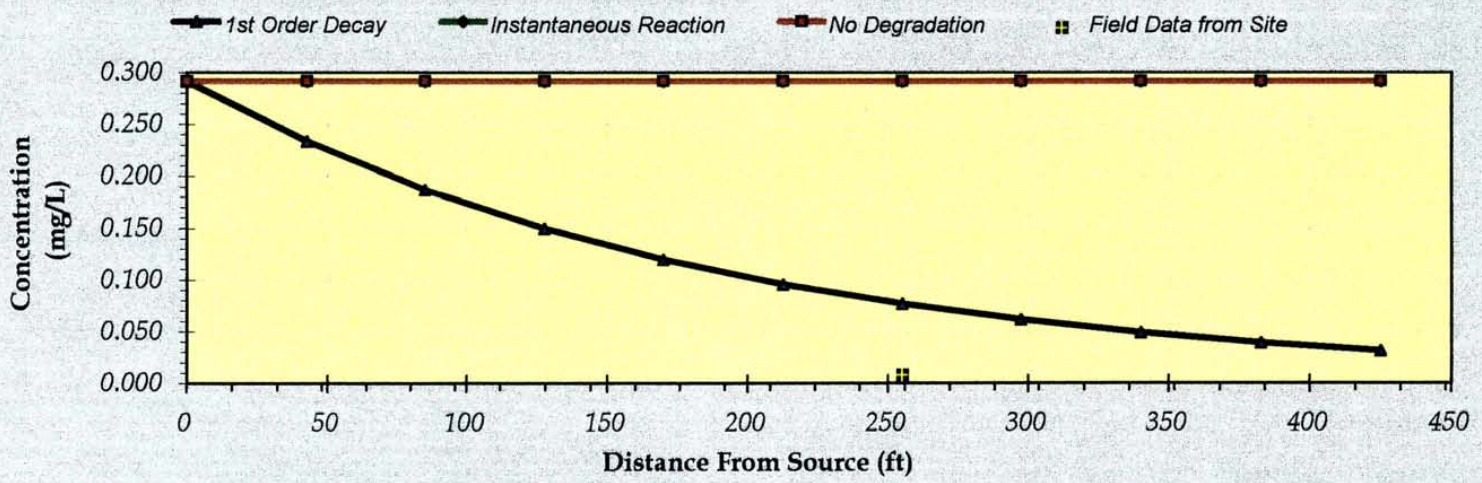
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ETHYLBENZENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292
1st Order Decay	0.292	0.234	0.187	0.149	0.120	0.096	0.077	0.061	0.049	0.039	0.031
Inst. Reaction	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292
Field Data from Site							0.008				



Calculate Animation

Time: 5.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Fluorene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	598.2	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	3.7E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.00588	*(ft/ft)*
Porosity	*n*	0.375	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	16.6	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	425	*(ft)*

3. ADSORPTION

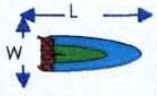
Retardation Factor*	*R*	25.1	*(-)*
or		or	
Soil Bulk Density	*rho*	1.325	*(kg/l)*
Partition Coefficient	*Koc*	7940	*(L/kg)*
FractionOrganicCarbon	*foc*	8.60E-04	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	2.1E+0	*(per yr)*
or		or	
Solute Half-Life	*t-half*	0.33	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	425	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	3	*(yr)*



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 *(ft)*

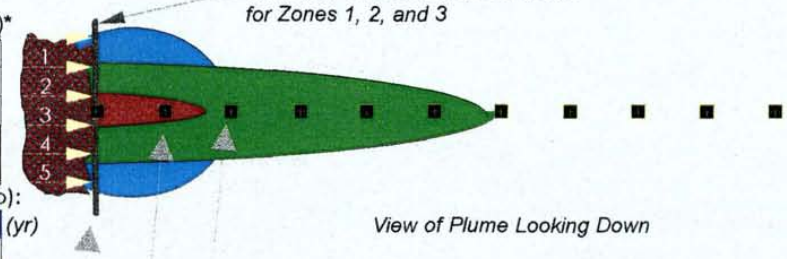
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.881
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	*(yr)*
Soluble Mass	or	
In NAPL, Soil	Infinite	*(Kg)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.043
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

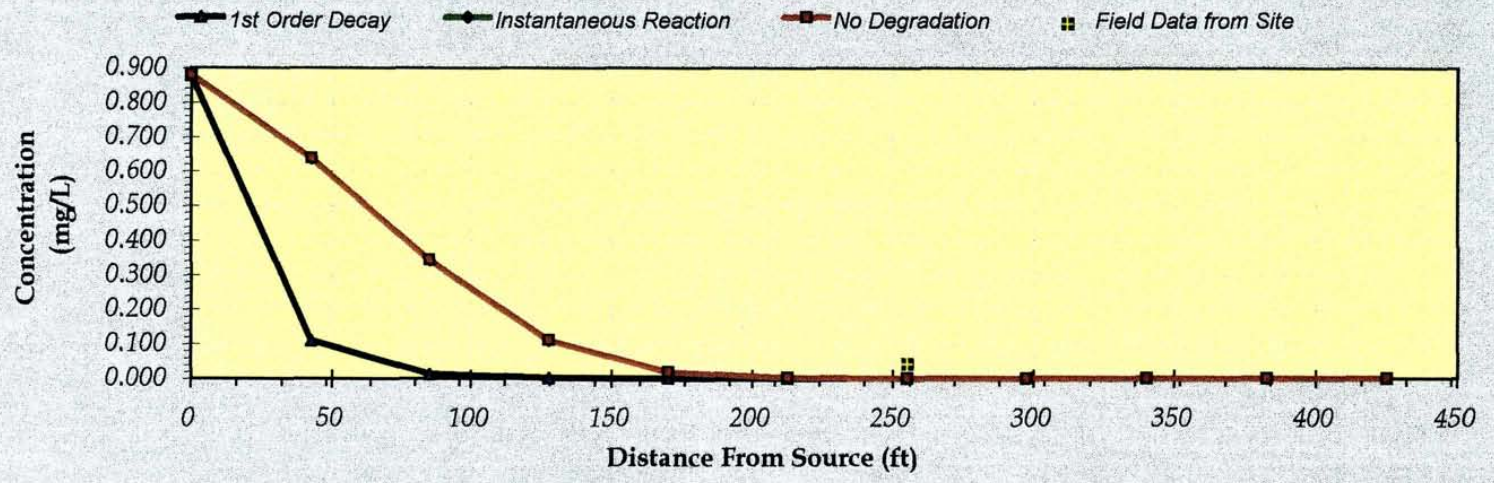
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED FLUORENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

TYPE OF MODEL	Distance from Source (ft) 0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.881	0.638	0.344	0.110	0.019	0.002	0.000	0.000	0.000	0.000	0.000
1st Order Decay	0.881	0.111	0.014	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.881	0.638	0.344	0.110	0.019	0.002	0.000	0.000	0.000	0.000	0.000
Field Data from Site							0.043				



Calculate Animation

Time: 3.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Naphthalene

Data Input Instructions:

115 ▸ 1. Enter value directly....or
or 2. Calculate by filling in grey
0.02 cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.
20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

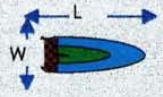
Retardation Factor*	R	4.9	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.8E-1	(per yr)
or		or	
Solute Half-Life	t-half	0.71	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	8	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

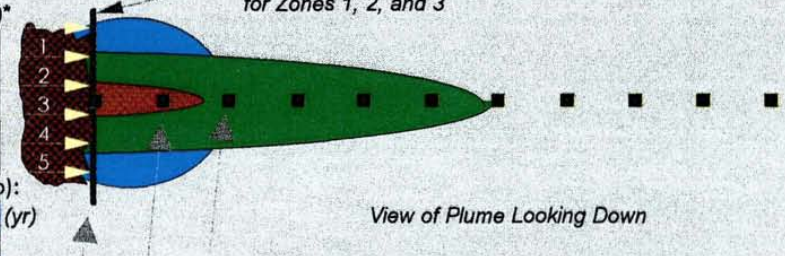
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	12.73
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	1.6
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

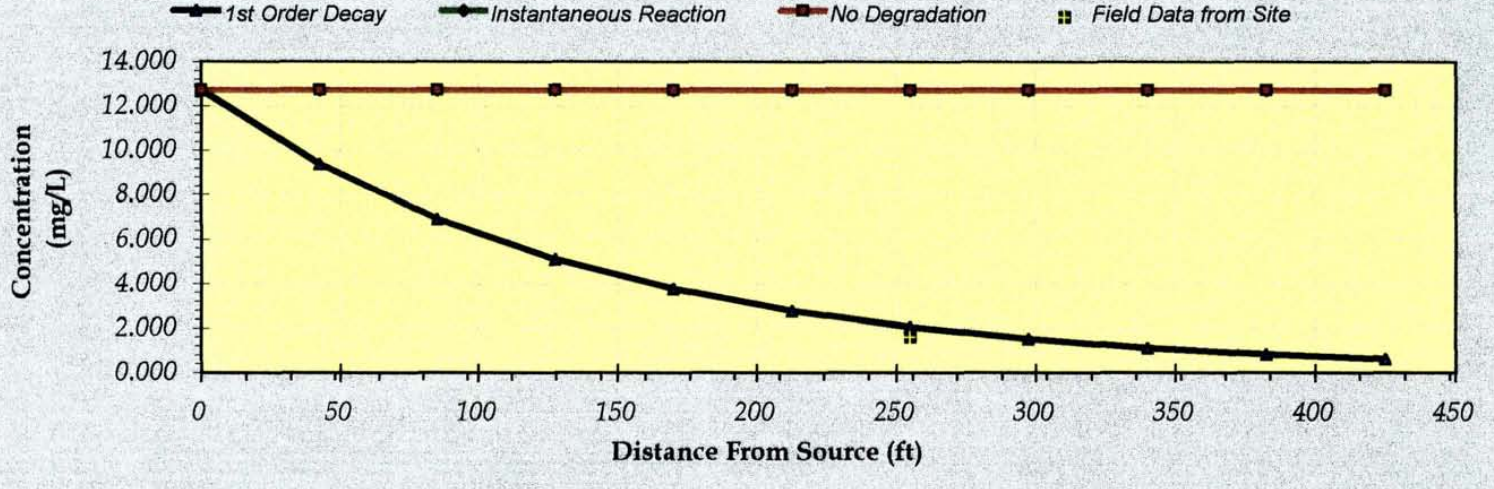
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	12.730	12.730	12.730	12.730	12.730	12.730	12.730	12.729	12.727	12.724	12.715
1st Order Decay	12.730	9.384	6.917	5.099	3.759	2.771	2.043	1.506	1.110	0.818	0.603
Inst. Reaction	12.730	12.730	12.730	12.730	12.730	12.730	12.730	12.729	12.727	12.724	12.715
Field Data from Site							1.600				



Calculate Animation

Time: 8.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Phenanthrene

Data Input Instructions:

115 → 1. Enter value directly....or
or → 2. Calculate by filling in grey
0.02 cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

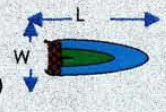
Retardation Factor*	R	39.3	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	12600	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.3E-1	(per yr)
or		or	
Solute Half-Life	t-half	1.10	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	9	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

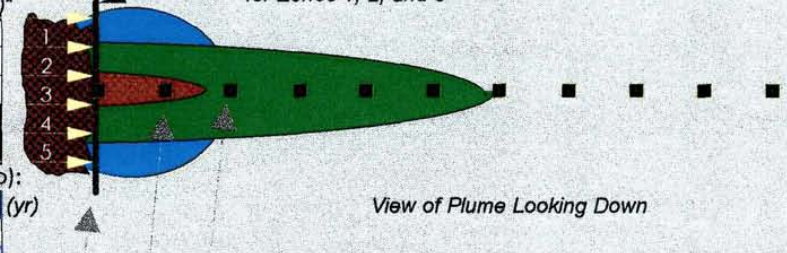
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.598
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.026
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

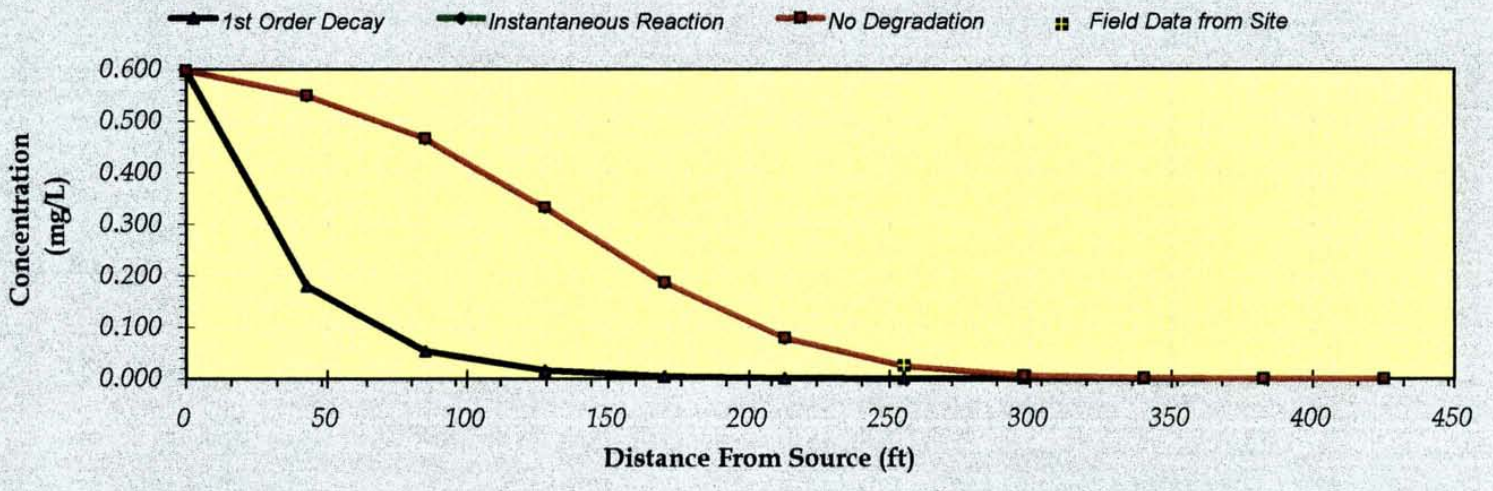
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED PHENANTHRENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

TYPE OF MODEL	Distance from Source (ft) 0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.598	0.550	0.466	0.333	0.187	0.079	0.024	0.005	0.001	0.000	0.000
1st Order Decay	0.598	0.180	0.054	0.016	0.005	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.598	0.550	0.466	0.333	0.187	0.079	0.024	0.005	0.001	0.000	0.000
Field Data from Site							0.026				



Calculate Animation

Time: 9.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Pyrene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

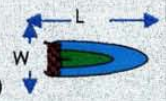
Retardation Factor*	R	116.5	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	38000	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.7E-2	(per yr)
or		or	
Solute Half-Life	t-half	10.40	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	74	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

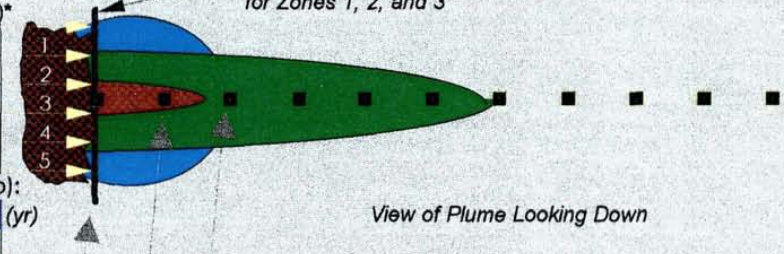
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.109
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.001					
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

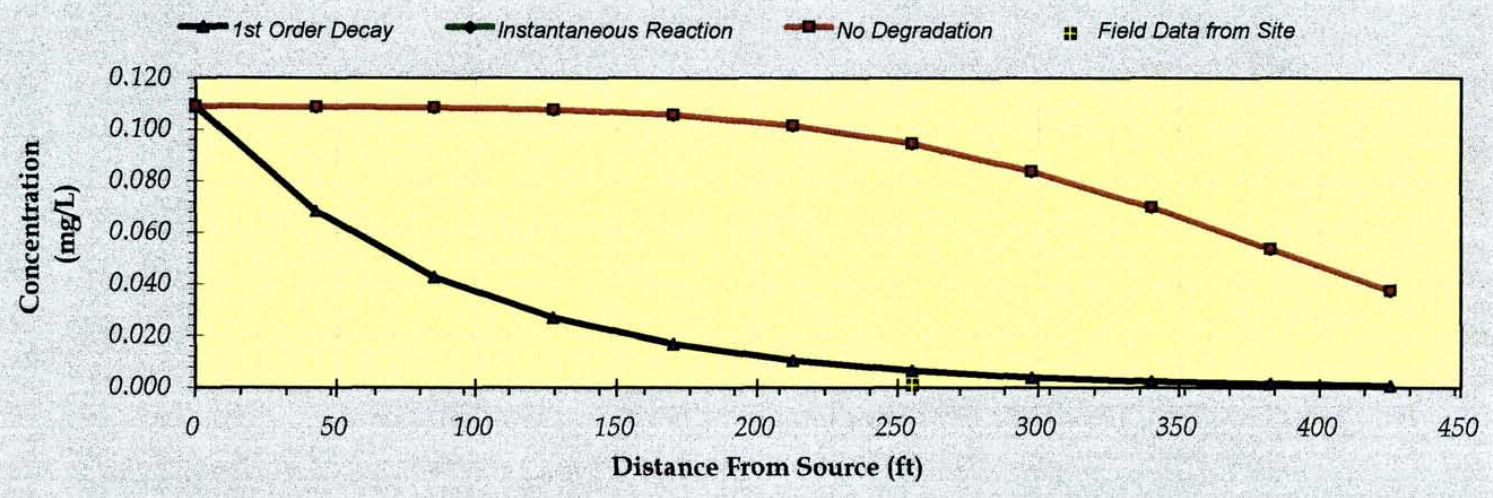
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED PYRENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

TYPE OF MODEL	Distance from Source (ft) 0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.109	0.109	0.109	0.108	0.106	0.102	0.095	0.084	0.070	0.054	0.038
1st Order Decay	0.109	0.068	0.043	0.027	0.017	0.011	0.007	0.004	0.002	0.001	0.001
Inst. Reaction	0.109	0.109	0.109	0.108	0.106	0.102	0.095	0.084	0.070	0.054	0.038
Field Data from Site							0.001				



Calculate Animation

Time: 74.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Toluene

Data Input Instructions:

115 ▸ 1. Enter value directly....or
or
0.02 ▸ 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.
20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

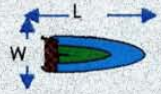
Retardation Factor*	R	1.8	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	257	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.0E+0	(per yr)
or		or	
Solute Half-Life	t-half	0.08	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*		425	(ft)
Modeled Area Width*		0	(ft)
Simulation Time*		0.7	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

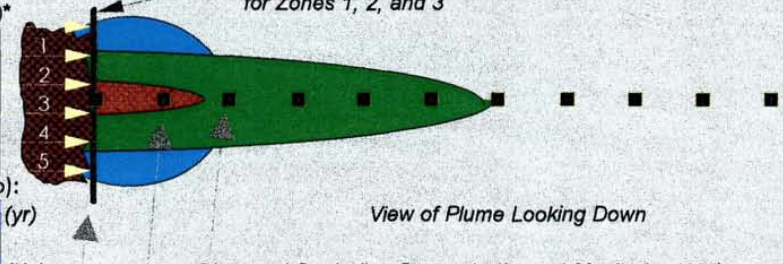
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	1.041
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.005
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

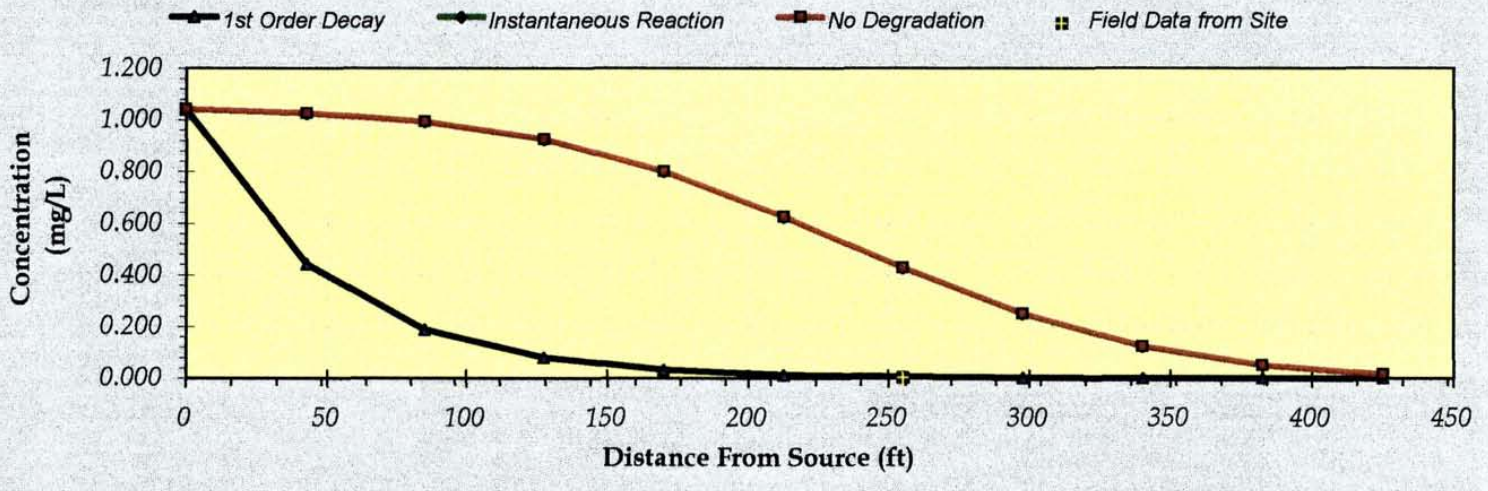
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED TOLUENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	**0**	**43**	**85**	**128**	**170**	**213**	**255**	**298**	**340**	**383**	**425**
No Degradation	1.041	1.026	0.995	0.925	0.801	0.626	0.428	0.250	0.122	0.049	0.016
1st Order Decay	1.041	0.443	0.188	0.080	0.034	0.014	0.006	0.002	0.001	0.000	0.000
Inst. Reaction	1.041	1.026	0.995	0.925	0.801	0.626	0.428	0.250	0.122	0.049	0.016
Field Data from Site							0.005				



Calculate Animation

Time:

0.70 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Xylenes

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.

20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

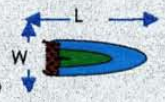
Retardation Factor*	R	3.1	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	692	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1	(per yr)
or		or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	6	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

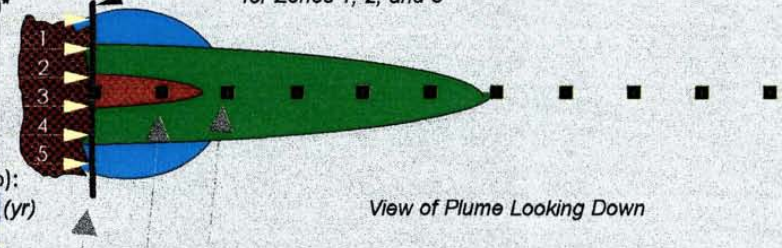
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.313
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.009
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

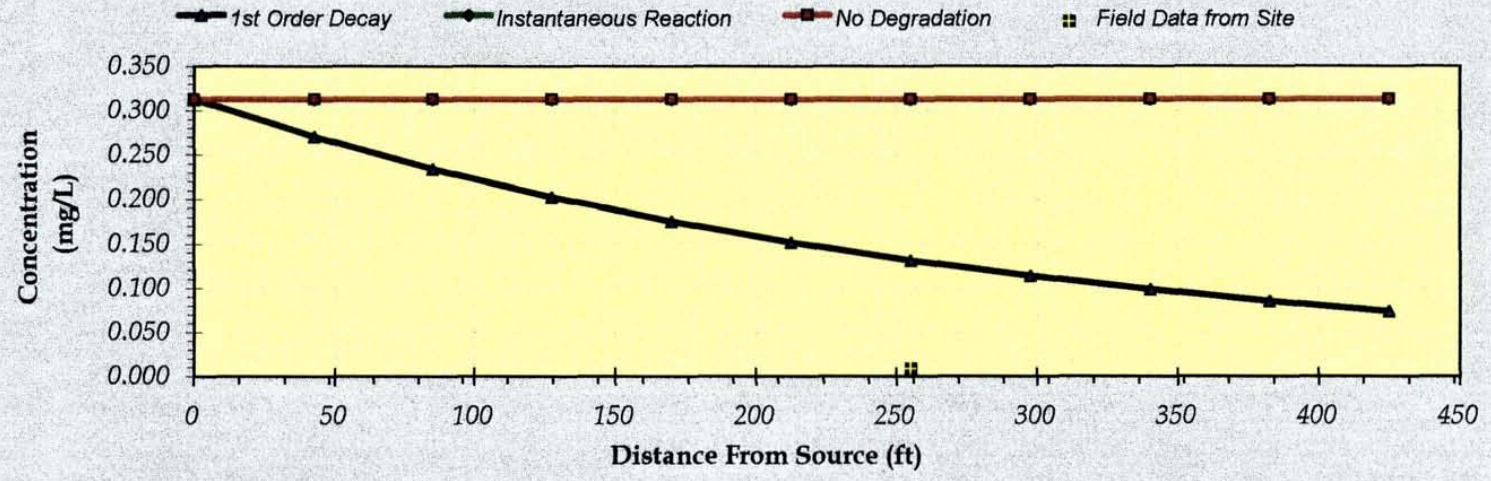
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED XYLENES CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	**0**	**43**	**85**	**128**	**170**	**213**	**255**	**298**	**340**	**383**	**425**
No Degradation	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313
1st Order Decay	0.313	0.271	0.234	0.203	0.176	0.152	0.131	0.114	0.098	0.085	0.074
Inst. Reaction	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313
Field Data from Site							0.009				



Calculate Animation

Time:

6.00 Years

Return to Input

Recalculate This Sheet

APPENDIX J

SCENARIO 4 - BIOSCREEN SIMULATIONS (SOUTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Benzene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.1	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

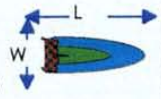
Retardation Factor*	R	1.2	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	64.6	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	3.5E-1	(per yr)
or		or	
Solute Half-Life	t-half	2.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	18	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

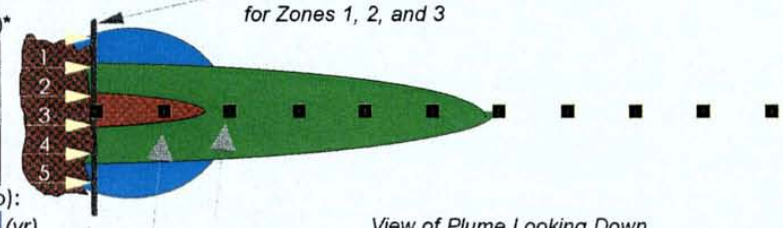
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	3.799
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

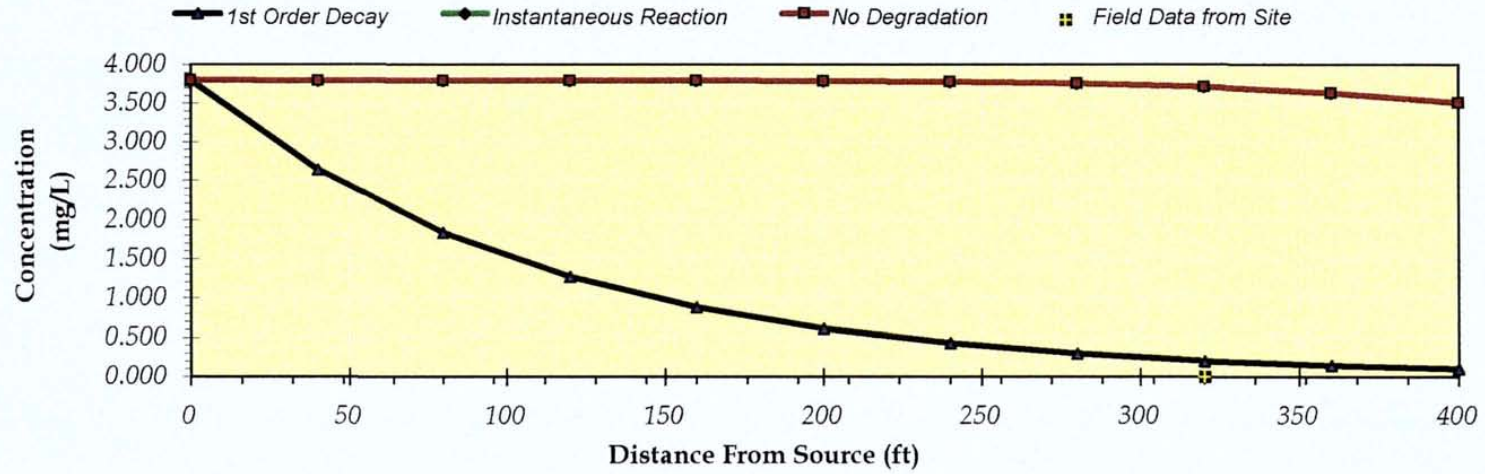
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED BENZENE CONCENTRATION ALONG PLUME CENTERLINE - SOUTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	3.799	3.799	3.799	3.798	3.796	3.791	3.780	3.758	3.714	3.636	3.509
1st Order Decay	3.799	2.640	1.835	1.275	0.886	0.616	0.428	0.298	0.207	0.144	0.100
Inst. Reaction	3.799	3.799	3.799	3.798	3.796	3.791	3.780	3.758	3.714	3.636	3.509
Field Data from Site									0.005		



Calculate Animation

Time:

18.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Ethylbenzene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.

20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.1	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

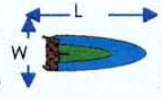
Retardation Factor*	R	3.1	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	676	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.1E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.62	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*		400	(ft)
Modeled Area Width*		0	(ft)
Simulation Time*		4	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

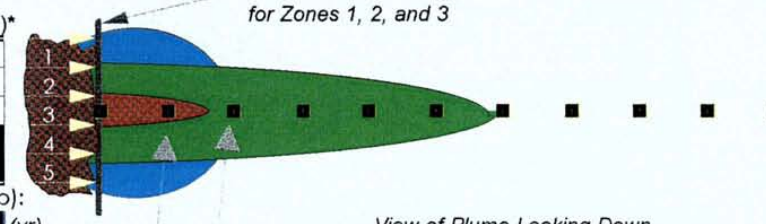
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	0.292
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

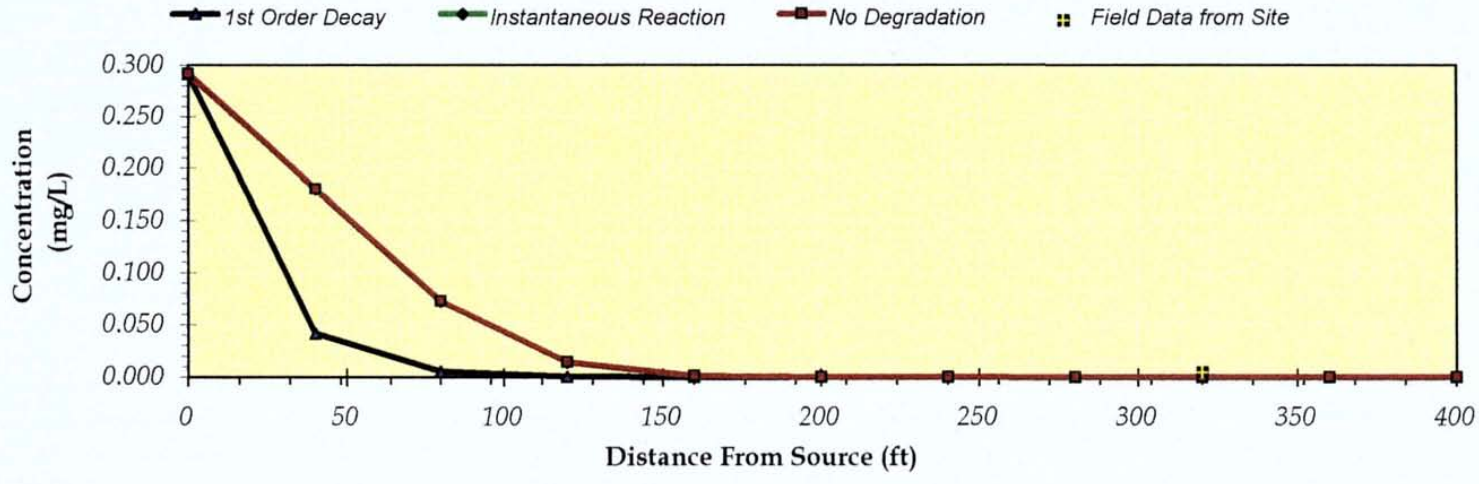
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ETHYLBENZENE CONCENTRATION ALONG PLUME CENTERLINE - SOUTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	0.292	0.180	0.072	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	0.292	0.042	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.292	0.180	0.072	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site									0.005		



Calculate Animation

Time: 4.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Naphthalene

Data Input Instructions:

115 or 0.02
1. Enter value directly....or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.
20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.1	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

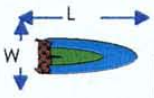
Retardation Factor*	R	4.9	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.8E-1	(per yr)
or		or	
Solute Half-Life	t-half	0.71	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	10	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

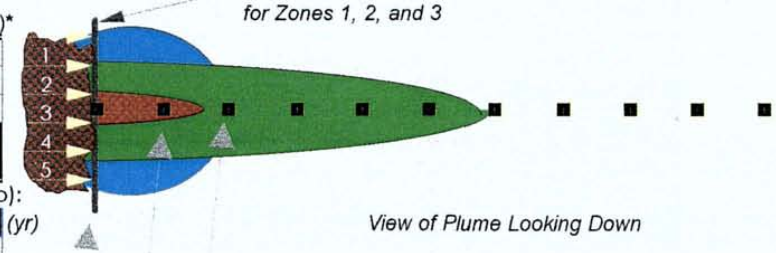
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	12.73
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.024
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

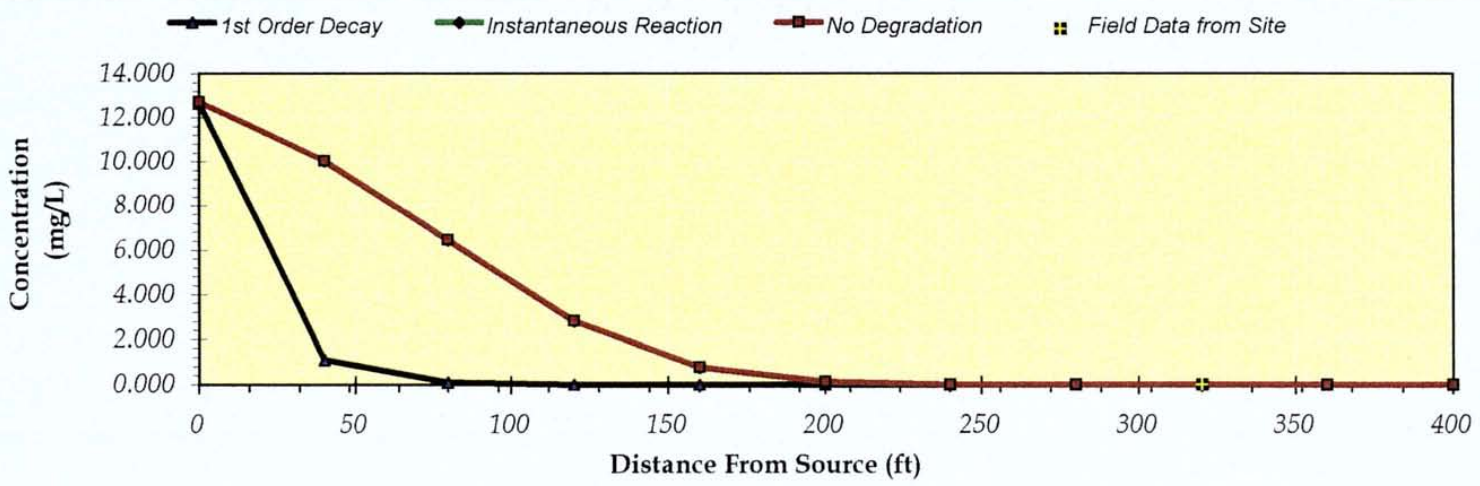
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION ALONG PLUME CENTERLINE - SOUTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	12.730	10.037	6.447	2.813	0.765	0.123	0.011	0.001	0.000	0.000	0.000
1st Order Decay	12.730	1.110	0.097	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	12.730	10.037	6.447	2.813	0.765	0.123	0.011	0.001	0.000	0.000	0.000
Field Data from Site									0.024		



Calculate Animation

Time: 10.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Toluene

Data Input Instructions:

115 or 0.02

1. Enter value directly....or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.

20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	39.8	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	2.5E-03	*(cm/sec)*
Hydraulic Gradient	*i*	0.00571	*(ft/ft)*
Porosity	*n*	0.375	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	16.1	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	400	*(ft)*

3. ADSORPTION

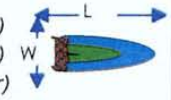
Retardation Factor*	*R*	1.8	*(-)*
or		or	
Soil Bulk Density	*rho*	1.325	*(kg/l)*
Partition Coefficient	*Koc*	257	*(L/kg)*
FractionOrganicCarbon	*foc*	8.60E-04	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	9.0E+0	*(per yr)*
or		or	
Solute Half-Life	*t-half*	0.08	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	400	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	0.8	*(yr)*



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 *(ft)*

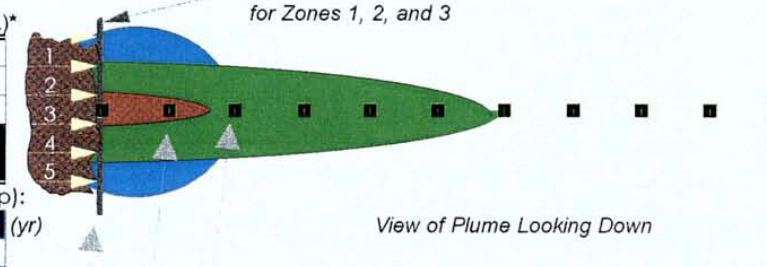
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	1.041
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	*(yr)*
Soluble Mass	or	
In NAPL, Soil	Infinite	*(Kg)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

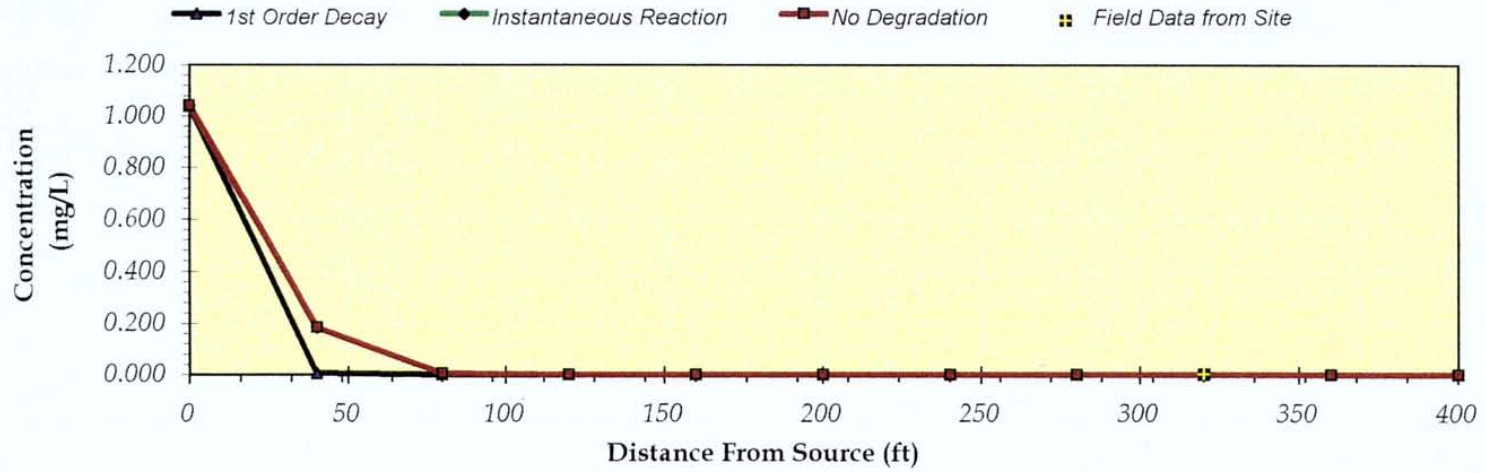
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED TOLUENE CONCENTRATION ALONG PLUME CENTERLINE - SOUTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	1.041	0.185	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	1.041	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	1.041	0.185	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site									0.005		



Calculate Animation

Time:

0.80 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Xylenes

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.1	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

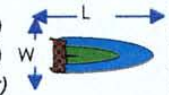
Retardation Factor*	R	3.1	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	692	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1	(per yr)
or		or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	8	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

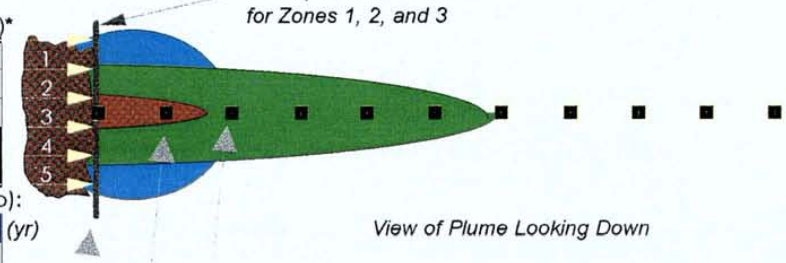
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	0.313
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

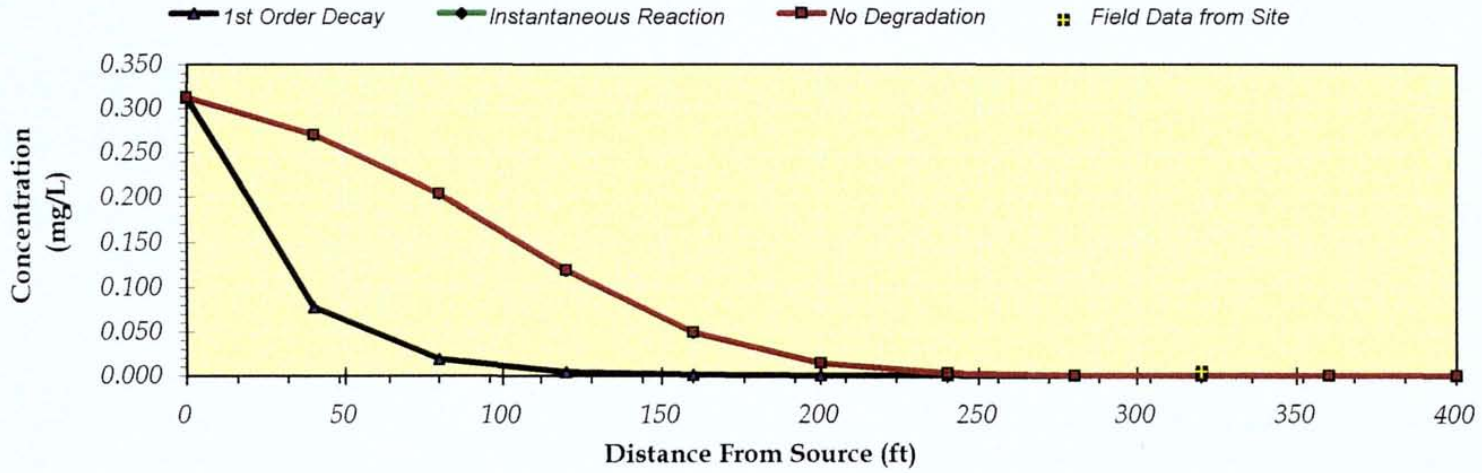
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED XYLENES CONCENTRATION ALONG PLUME CENTERLINE - SOUTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	0.313	0.270	0.204	0.119	0.050	0.014	0.003	0.000	0.000	0.000	0.000
1st Order Decay	0.313	0.078	0.019	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.313	0.270	0.204	0.119	0.050	0.014	0.003	0.000	0.000	0.000	0.000
Field Data from Site									0.005		



Calculate Animation

Time: 8.00 Years

Return to Input

Recalculate This Sheet

APPENDIX K

BIOSCREEN SIMULATION OF PAHs (NORTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Acenaphthene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.

20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	598.2	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	3.7E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.00588	*(ft/ft)*
Porosity	*n*	0.375	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	16.6	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	425	*(ft)*

3. ADSORPTION

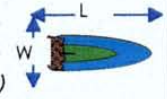
Retardation Factor*	*R*	16.2	*(-)*
or		or	
Soil Bulk Density	*rho*	1.325	*(kg/l)*
Partition Coefficient	*Koc*	5010	*(L/kg)*
FractionOrganicCarbon	*foc*	8.60E-04	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	5.8E-1	*(per yr)*
or		or	
Solute Half-Life	*t-half*	1.19	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	425	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	12	*(yr)*



6. SOURCE DATA

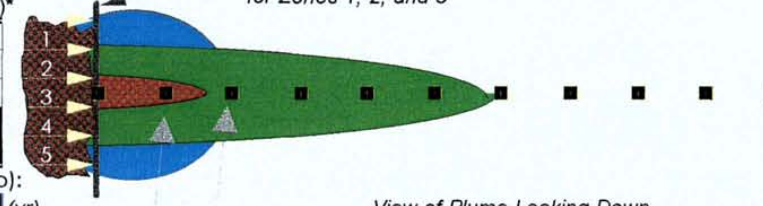
Source Thickness in Sat.Zone* 15 *(ft)*

Source Zones: Width* (ft)	Conc. (mg/L)*
175	1.785
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	*(yr)*
Soluble Mass	or	
In NAPL, Soil	Infinite	*(Kg)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.065				
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

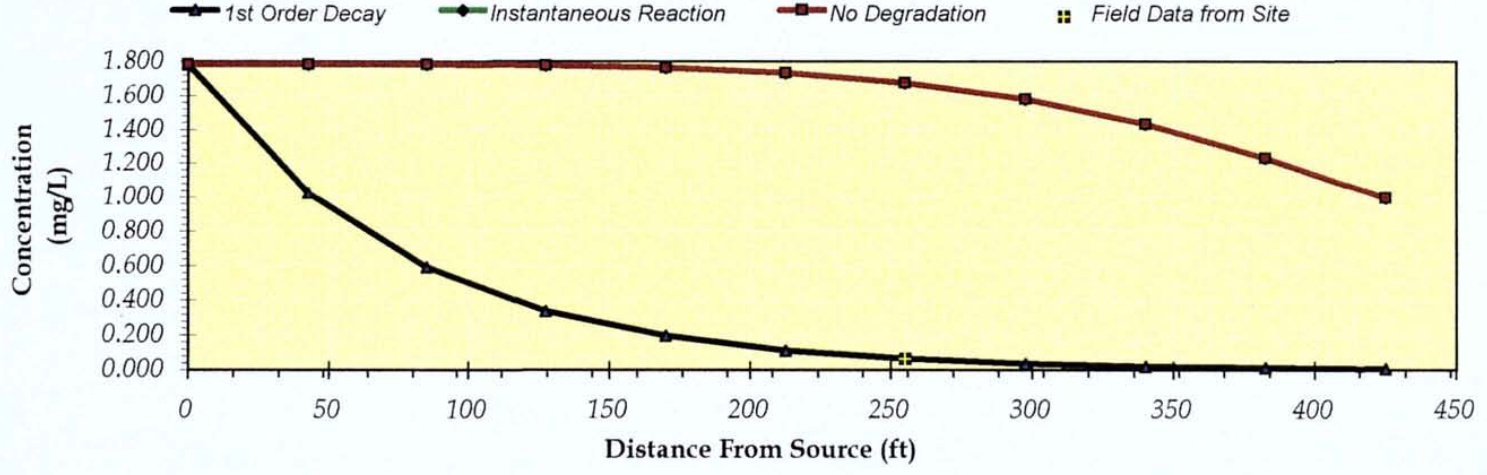
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ACENAPHTHENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	1.785	1.784	1.782	1.777	1.763	1.734	1.677	1.579	1.430	1.231	0.995
1st Order Decay	1.785	1.027	0.591	0.340	0.196	0.113	0.065	0.037	0.021	0.012	0.007
Inst. Reaction	1.785	1.784	1.782	1.777	1.763	1.734	1.677	1.579	1.430	1.231	0.995
Field Data from Site							0.065				



Calculate Animation

Time: 12.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Fluorene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.

20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

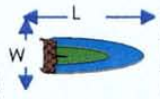
Retardation Factor*	R	25.1	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	7940	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	3.4E-1	(per yr)
or		or	
Solute Half-Life	t-half	2.05	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	21	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

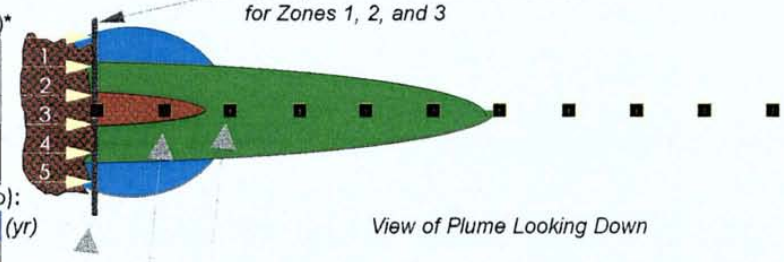
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.881
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.043				
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

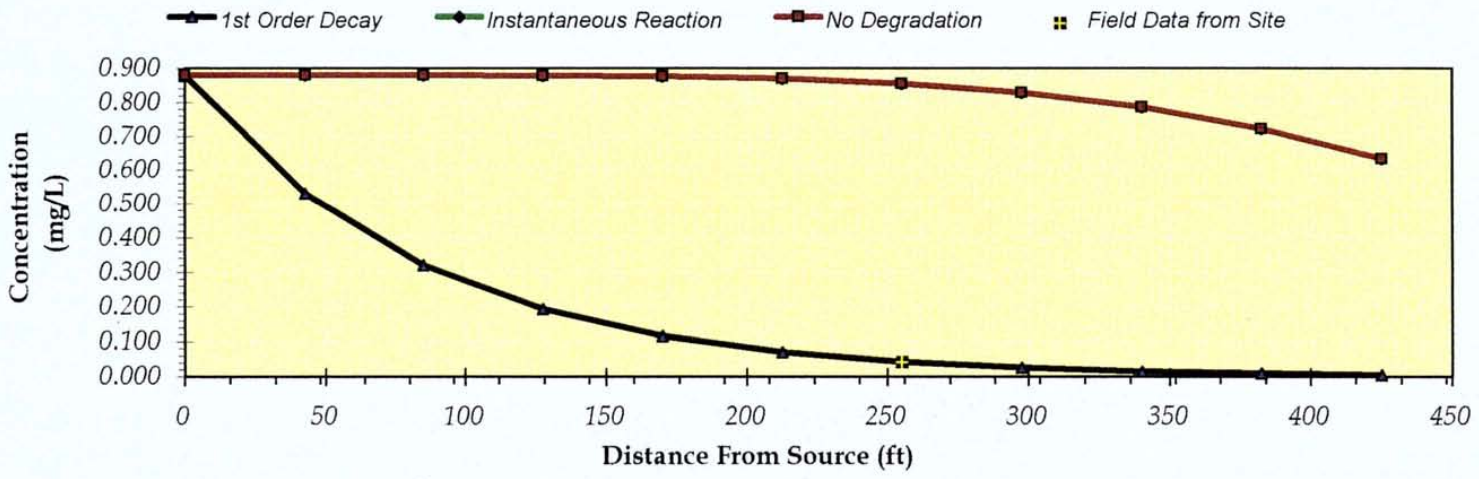
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED FLUORENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.881	0.881	0.880	0.879	0.876	0.870	0.856	0.830	0.787	0.722	0.634
1st Order Decay	0.881	0.532	0.321	0.194	0.117	0.071	0.043	0.026	0.016	0.009	0.006
Inst. Reaction	0.881	0.881	0.880	0.879	0.876	0.870	0.856	0.830	0.787	0.722	0.634
Field Data from Site							0.043				



Calculate Animation

Time:

21.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Phenanthrene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	598.2	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	3.7E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.00588	*(ft/ft)*
Porosity	*n*	0.375	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	16.6	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	425	*(ft)*

3. ADSORPTION

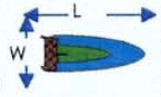
Retardation Factor*	*R*	39.3	*(-)*
or		or	
Soil Bulk Density	*rho*	1.325	*(kg/l)*
Partition Coefficient	*Koc*	12600	*(L/kg)*
FractionOrganicCarbon	*foc*	8.60E-04	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	2.3E-1	*(per yr)*
or		or	
Solute Half-Life	*t-half*	3.07	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	425	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	24	*(yr)*



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 *(ft)*

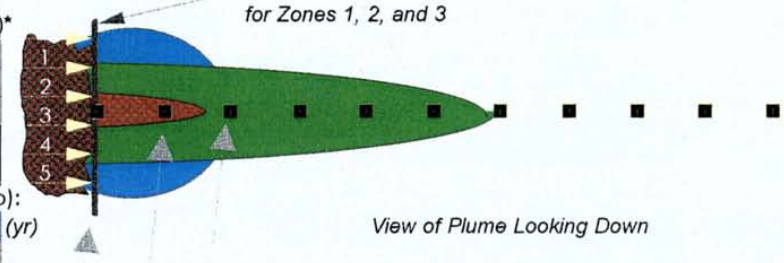
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.598
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	*(yr)*
Soluble Mass	or	
In NAPL, Soil	Infinite	*(Kg)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.026					
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

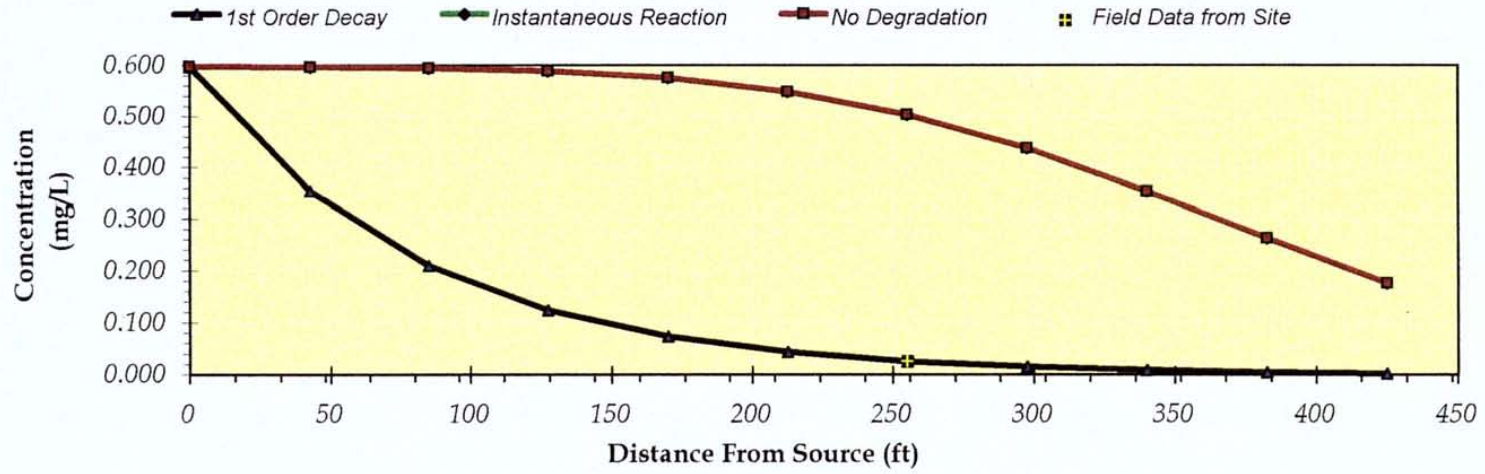
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED PHENANTHRENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.598	0.597	0.595	0.589	0.575	0.549	0.504	0.437	0.354	0.262	0.176
1st Order Decay	0.598	0.354	0.210	0.124	0.074	0.044	0.026	0.015	0.009	0.005	0.003
Inst. Reaction	0.598	0.597	0.595	0.589	0.575	0.549	0.504	0.437	0.354	0.262	0.176
Field Data from Site							0.026				



Calculate Animation

Time:

24.00 Years

Return to Input

Recalculate This Sheet

APPENDIX L

BIOSCREEN SIMULATION OF BENZENE (NORTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.3

South Cavalcade
North Area
Benzene

Data Input Instructions:

115 → 1. Enter value directly....or
or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	82.2	(ft/yr)
or		or	
Hydraulic Conductivity	K	7.8E-03	(cm/sec)
Hydraulic Gradient	i	0.00382	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

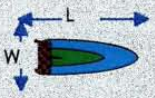
Retardation Factor*	R	1.7	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	64.6	(L/kg)
FractionOrganicCarbon	foc	3.28E-03	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.9E-1	(per yr)
or		or	
Solute Half-Life	t-half	0.70	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	8	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

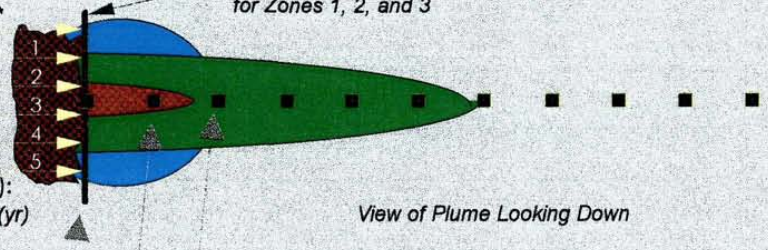
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	3.799
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.006
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

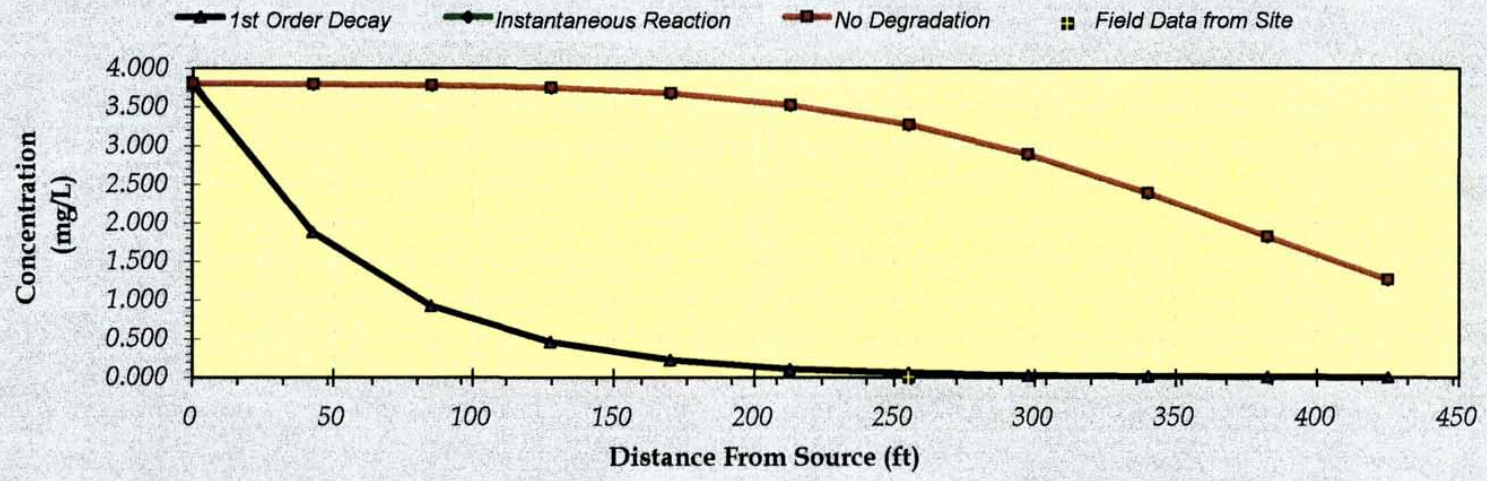
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

000770

DISSOLVED BENZENE CONCENTRATION ALONG PLUME CENTERLINE - NORTH AREA (mg/L)

	Distance from Source (ft)										
TYPE OF MODEL	**0**	**43**	**85**	**128**	**170**	**213**	**255**	**298**	**340**	**383**	**425**
No Degradation	3.799	3.794	3.782	3.750	3.676	3.528	3.271	2.885	2.381	1.813	1.256
1st Order Decay	3.799	1.882	0.932	0.462	0.229	0.113	0.056	0.028	0.014	0.007	0.003
Inst. Reaction	3.799	3.794	3.782	3.750	3.676	3.528	3.271	2.885	2.381	1.813	1.256
Field Data from Site							0.006				



Calculate Animation

Time: 8.00 Years

Return to Input

Recalculate This Sheet

APPENDIX M

BIOSCREEN SIMULATIONS OF BENZENE (SOUTHERN AREA)

KEY ENVIRONMENTAL INCORPORATED

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Benzene

Data Input Instructions:

115 or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* ▸ Data used directly in model.

20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	18.5	(ft/yr)
or		or	
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.00414	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.1	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

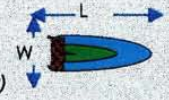
Retardation Factor*	R	1.7	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	64.6	(L/kg)
FractionOrganicCarbon	foc	3.28E-03	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1	(per yr)
or		or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	13	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

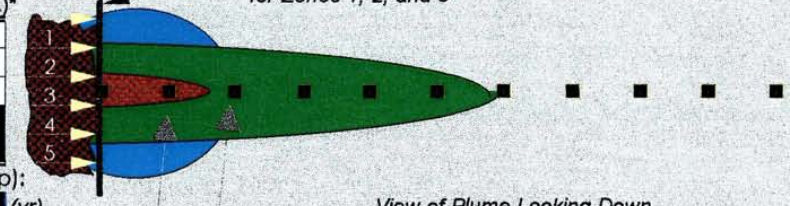
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	3.799
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

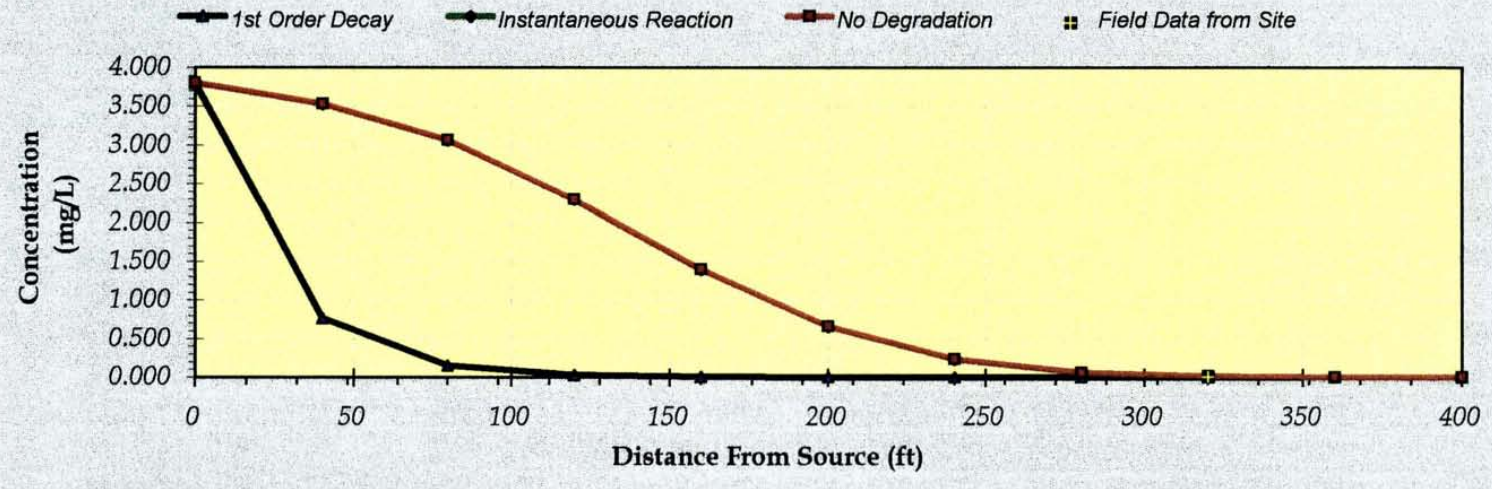
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED BENZENE CONCENTRATION ALONG PLUME CENTERLINE - SOUTH AREA (mg/L)

Distance from Source (ft)

TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	3.799	3.529	3.065	2.295	1.398	0.660	0.234	0.061	0.012	0.002	0.000
1st Order Decay	3.799	0.770	0.156	0.032	0.006	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	3.799	3.529	3.065	2.295	1.398	0.660	0.234	0.061	0.012	0.002	0.000
Field Data from Site									0.005		



Calculate Animation

Time:

13.00 Years

Return to Input

Recalculate This Sheet

APPENDIX N

BIOSCREEN SIMULATIONS UNDER PUMPING CONDITIONS

KEY ENVIRONMENTAL INCORPORATED

CALCULATION BRIEF

GROUNDWATER MODELING OF THE EFFECTS OF A HYPOTHETICAL OFF-SITE PUMPING WELL - SOUTH CAVALCADE SUPERFUND SITE, HOUSTON, TEXAS

This calculation brief presents the results of the evaluation of the potential effects of hypothetical off-Site pumping wells in the shallow groundwater zone downgradient of the South Cavalcade Site. The approach used in this evaluation involved the use of a groundwater flow model to estimate hydraulic gradients under pumping conditions for segments along the flow path from constituent source to the hypothetical pumping well. These data were used to calculate an average hydraulic gradient under pumping conditions for the area between the constituent source and the hypothetical pumping well. This average hydraulic gradient was used as an input to the BIOSCREEN model to simulate the effects of off-Site pumping on the natural attenuation of the constituents of interest.

Hydraulic gradients and corresponding travel times toward the hypothetical well under pumping conditions were calculated using available hydrogeologic data. Known data include natural hydraulic gradients, hydraulic conductivity, and saturated aquifer thickness. Distance from the constituent source to the hypothetical off-Site pumping well, groundwater extraction rate, groundwater recharge rate, and aquifer porosity are assumed for the modeling. Values for known parameters were selected from prior investigations and literature values. The selected hydraulic conductivity values were 105 feet per day (ft/day) for the North Area and 7.2 ft/day for the South Area. These values were obtained from pumping test evaluations[1,2].

The extraction well was modeled to be 400 feet downgradient from the chemical constituent source in the North Area, or 425 feet downgradient from the source in the South Area. Groundwater recharge was estimated as 0.0001 ft/day as rainfall using the Hydrologic Evaluation of Landfill Performance (HELP) model[3]. The selected saturated aquifer thickness was 15 feet. Volumetric aquifer porosity was selected as 0.375. A groundwater extraction rate of 0.5 gallons per minute (gpm) was selected. This pumping rate is equal to 720 gallons per day, which should be a sufficient supply for residential purposes.

A proprietary groundwater flow model which uses Microsoft Excel as a platform was used to calculate a hydraulic head matrix based on input variables for hydraulic conductivity (K), groundwater extraction rate (Q), saturated aquifer thickness (B), and groundwater recharge rate

---

[1] Keystone Environmental Resources, Inc., 1992. *Extraction Well Pilot Study Report, South Cavalcade Site, Houston, Texas.*

[2] McLaren-Hart Environmental Engineering Corporation, 1993. *Groundwater Collection Trench Pilot Study Report.*

[3] McLaren-Hart Environmental Engineering Corporation, 1994. *100% Design Groundwater Collection and Reinjection System and Dense Non-Aqueous Phase Liquid Recovery System - South Cavalcade Superfund Site, Houston, Texas.*

(N). The rectangular model domain was 600 feet long (in the direction of normal groundwater flow) and 300 feet wide. The following boundary conditions were used:

- the two model boundaries which lie parallel to the groundwater flow direction were defined as no-flow boundaries; and,
- the two model boundaries which lie perpendicular to the groundwater flow direction (upgradient and downgradient) were defined as constant-head boundaries.

The pumping well was located 120 feet upgradient of the downgradient constant-head boundary. The source area is considered to be 400 feet (North Area) or 425 feet (South Area) upgradient of the pumping well, and thus lies in the model domain.

The upgradient constant-head boundary was modeled with a hydraulic head 3.42 feet greater than the downgradient boundary. The average hydraulic gradient over the model domain was then set equal to 0.0059 feet per foot (ft/ft), which matches the field observed hydraulic gradient.

Both natural (non-pumping) and pumping scenarios were modeled. Using the known parameters (hydraulic conductivity, hydraulic gradients, and assumed porosity), the unknown values (groundwater velocity and average travel time over discrete intervals) were calculated using the relations

$$v_{avg} = K I / n$$

and

$$t_{avg} = x / v_{avg}.$$

The travel times were then summed to calculate an average hydraulic gradient from the source area to the extraction well. Aquifer parameters including average hydraulic gradient from source area to receptor area, hydraulic conductivity, saturated aquifer thickness, and aquifer porosity were input into a natural attenuation model for purposes of evaluating the effects of the hypothetical extraction well on natural attenuation of the constituents of interest.

Tables 1 and 2, respectively, list the hydraulic gradients and water level drawdowns which result from groundwater pumping in the North and South Areas. The gradients are listed under both natural (non-pumping) and pumping conditions. Drawdown curves which compare pumping conditions and non-pumping conditions for both simulations are shown in Figures 1 and 2.

The average hydraulic gradient which resulted from the non-pumping conditions was equal to the field observed conditions. The hydraulic gradient toward the well increased slightly to moderately for the modeled pumping scenarios. For the North Area simulation, drawdowns are small along the entire flow path (<0.10 feet), and hydraulic gradients toward the hypothetical well increase significantly (>10% increase) only within 15 feet of the well. Travel time from the

constituent source area to the pumping well decreases by only 5 days due to groundwater extraction. For the South Area simulation, drawdowns are of much greater magnitude (>0.10 feet) to a radial distance of 340 feet from the extraction well. Average hydraulic gradient increases by a moderate amount for this simulation, but the travel time from source area to the extraction well remains quite long (>8 years).

TABLE 1. SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Hydraulic Gradient and Drawdown Summary

North Area
Q = 0.5 gpm (96 ft3/day)
K = 38150 ft/yr (105 ft/day)
Saturated Thickness (B) = 15 ft
Recharge (N) = 0.0001 ft/day
Porosity (n) = 0.375

Distance from Pumping Well (ft)	Hydraulic Gradient (Non-pumping)	Travel Time (days)	Hydraulic Gradient (Pumping)	Travel Time (days)	Drawdown (feet)
0-5	0.0059	3.0	0.0089	2.0	0.06
5-10	0.0059	3.0	0.0072	2.5	0.04
10-15	0.0059	3.0	0.0066	2.7	0.04
15-20	0.0059	3.0	0.0064	2.8	0.03
20-25	0.0059	3.0	0.0063	2.8	0.03
25-30	0.0059	3.0	0.0062	2.9	0.03
30-35	0.0059	3.0	0.0061	2.9	0.03
35-40	0.0059	3.0	0.0061	2.9	0.02
40-45	0.0059	3.0	0.0061	2.9	0.02
45-50	0.0059	3.0	0.0060	3.0	0.02
50-55	0.0059	3.0	0.0060	3.0	0.02
55-60	0.0059	3.0	0.0060	3.0	0.02
60-65	0.0059	3.0	0.0060	3.0	0.02
65-70	0.0059	3.0	0.0060	3.0	0.02
70-75	0.0059	3.0	0.0060	3.0	0.02
75-80	0.0059	3.0	0.0060	3.0	0.02
80-85	0.0059	3.0	0.0059	3.0	0.02
85-90	0.0059	3.0	0.0059	3.0	0.02
90-95	0.0059	3.0	0.0059	3.0	0.02
95-100	0.0059	3.0	0.0059	3.0	0.02
100-106	0.0059	3.6	0.0059	3.6	0.02
106-113	0.0059	4.2	0.0059	4.2	0.02
113-121	0.0058	4.9	0.0059	4.8	0.02
121-130	0.0058	5.5	0.0059	5.4	0.01
130-140	0.0058	6.2	0.0059	6.1	0.01
140-150	0.0058	6.2	0.0059	6.1	0.01
150-160	0.0058	6.2	0.0059	6.1	0.01
160-170	0.0058	6.2	0.0059	6.1	0.01
170-180	0.0058	6.2	0.0059	6.1	0.01
180-190	0.0058	6.2	0.0059	6.1	0.01
190-200	0.0058	6.2	0.0059	6.1	0.01
200-215	0.0058	9.2	0.0059	9.1	0.01
215-230	0.0058	9.2	0.0059	9.1	0.01
230-245	0.0058	9.2	0.0059	9.1	0.01
245-260	0.0058	9.2	0.0059	9.1	0.01
260-280	0.0058	12.3	0.0059	12.1	0.01
280-300	0.0058	12.3	0.0059	12.1	0.01
300-320	0.0058	12.3	0.0059	12.1	0.01
320-340	0.0058	12.3	0.0059	12.1	0.01
340-360	0.0058	12.3	0.0058	12.3	0.01
360-380	0.0058	12.3	0.0058	12.3	0.00
380-400	0.0058	12.3	0.0058	12.3	0.00
Total travel time (days)		245		240	
Average gradient (ft/ft)	0.0058		0.0060		

rjh c:\scav\96-118\gwmodel.xls

TABLE 2. SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Hydraulic Gradient and Drawdown Summary

South Area
Q = 0.5 gpm (96 ft3/day)
K = 2612 ft/yr (7.2 ft/day)
B = 15 ft
N = 0.0001 ft/day
Porosity (n) = 0.375

Distance from Pumping Well (ft)	Hydraulic Gradient (Non-pumping)	Travel Time (days)	Hydraulic Gradient (Pumping)	Travel Time (days)	Drawdown (feet)
0-5	0.0061	42.7	0.0495	5.3	0.82
5-10	0.0060	43.4	0.0253	10.3	0.61
10-15	0.0060	43.4	0.0170	15.3	0.51
15-20	0.0060	43.4	0.0135	19.3	0.46
20-25	0.0060	43.4	0.0116	22.4	0.42
25-30	0.0060	43.4	0.0104	25.0	0.39
30-35	0.0060	43.4	0.0096	27.1	0.37
35-40	0.0060	43.4	0.0091	28.6	0.35
40-45	0.0060	43.4	0.0086	30.3	0.34
45-50	0.0060	43.4	0.0083	31.4	0.32
50-55	0.0060	43.4	0.0080	32.6	0.31
55-60	0.0060	43.4	0.0078	33.4	0.30
60-65	0.0060	43.4	0.0076	34.3	0.29
65-70	0.0060	43.4	0.0075	34.7	0.28
70-75	0.0060	43.4	0.0074	35.2	0.28
75-80	0.0060	43.4	0.0072	36.2	0.27
80-85	0.0059	44.1	0.0072	36.2	0.26
85-90	0.0059	44.1	0.0071	36.7	0.26
90-95	0.0059	44.1	0.0070	37.2	0.25
95-100	0.0059	44.1	0.0069	37.7	0.25
100-106	0.0059	53.0	0.0069	45.3	0.24
106-113	0.0059	61.8	0.0068	53.6	0.23
113-121	0.0059	70.6	0.0068	61.3	0.23
121-130	0.0059	79.4	0.0067	70.0	0.22
130-140	0.0059	88.3	0.0067	77.7	0.22
140-150	0.0059	88.3	0.0066	78.9	0.21
150-160	0.0059	88.3	0.0066	78.9	0.20
160-170	0.0059	88.3	0.0065	80.1	0.19
170-180	0.0058	89.8	0.0065	80.1	0.19
180-190	0.0058	89.8	0.0065	80.1	0.18
190-200	0.0058	89.8	0.0065	80.1	0.17
200-215	0.0058	134.7	0.0064	122.1	0.17
215-230	0.0058	134.7	0.0064	122.1	0.16
230-245	0.0058	134.7	0.0064	122.1	0.15
245-260	0.0058	134.7	0.0064	122.1	0.14
260-280	0.0057	182.7	0.0064	162.8	0.13
280-300	0.0057	182.7	0.0063	165.3	0.12
300-320	0.0057	182.7	0.0063	165.3	0.11
320-340	0.0057	182.7	0.0063	165.3	0.10
340-360	0.0057	182.7	0.0063	165.3	0.08
360-380	0.0056	186.0	0.0062	168.0	0.07
380-400	0.0056	186.0	0.0062	168.0	0.06
400-420	0.0056	186.0	0.0062	168.0	0.05
Total travel time (days)		3768		3172	
Average gradient (ft/ft)	0.0059		0.0070		

rjh c:\scav\96-118\gwmodel.xls

FIGURE 1. SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Modeled Hydraulic Heads in North Area: Q=0.5 gpm, K=105 ft/day

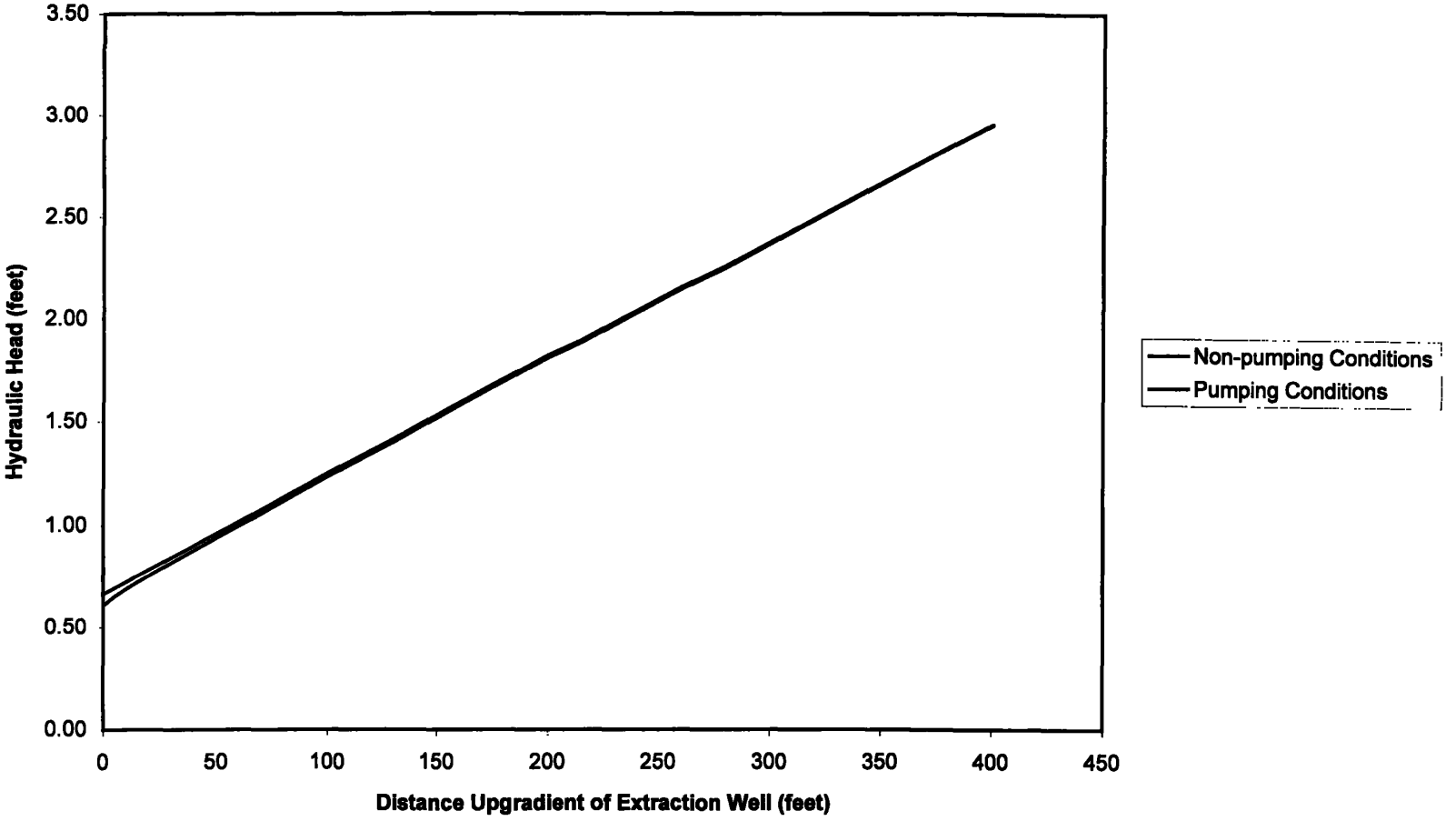
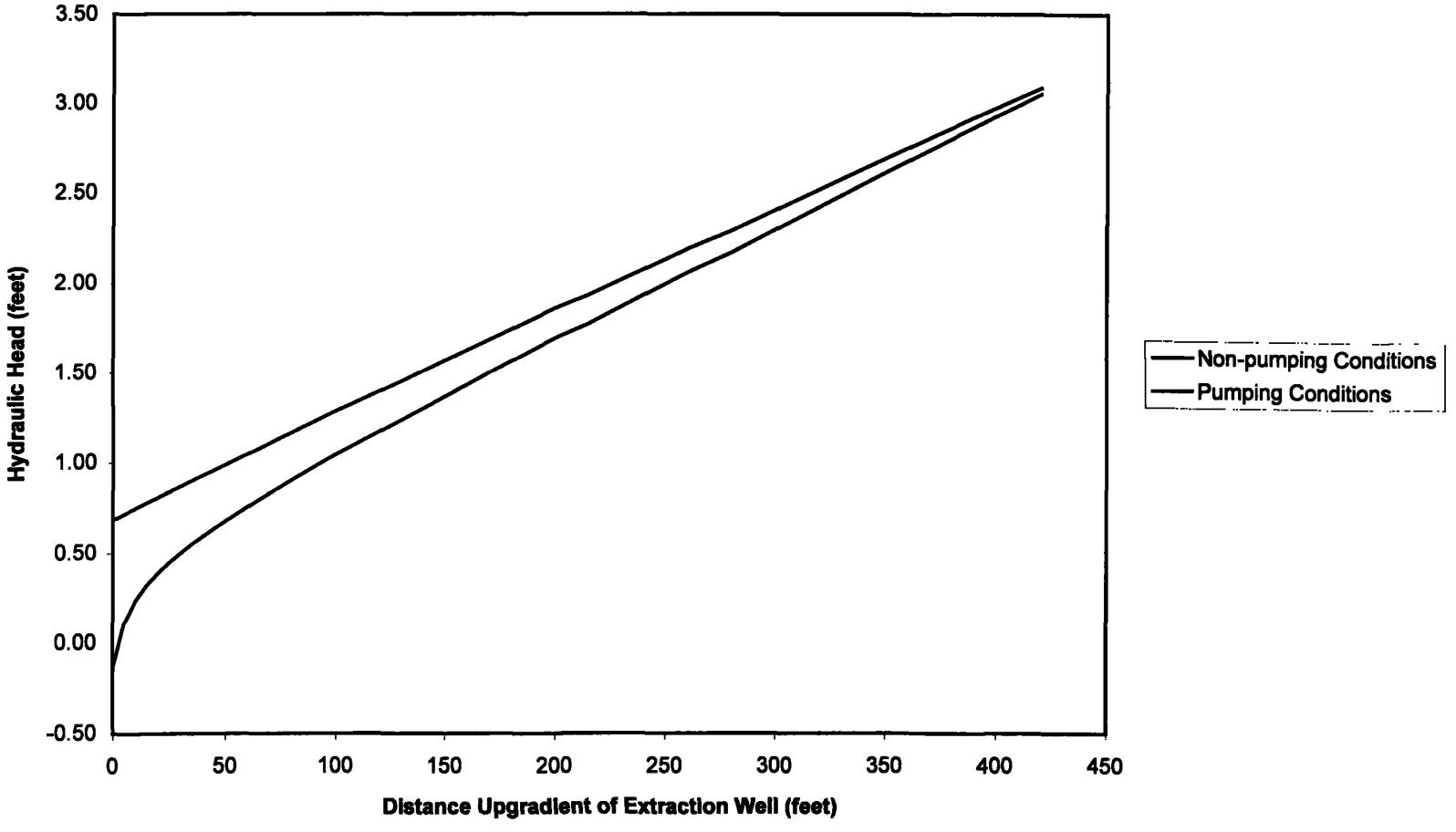


FIGURE 2. SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Modeled Hydraulic Heads in South Area: Q=0.5 gpm, K=7.2 ft/day



BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Acenaphthene

Data Input Instructions:
115 or 0.02 → 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

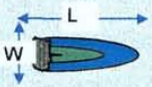
Retardation Factor*	R	16.2	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	5010	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.2E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.56	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	6	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

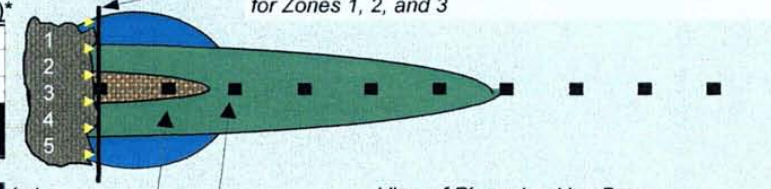
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	1.785
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.065
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

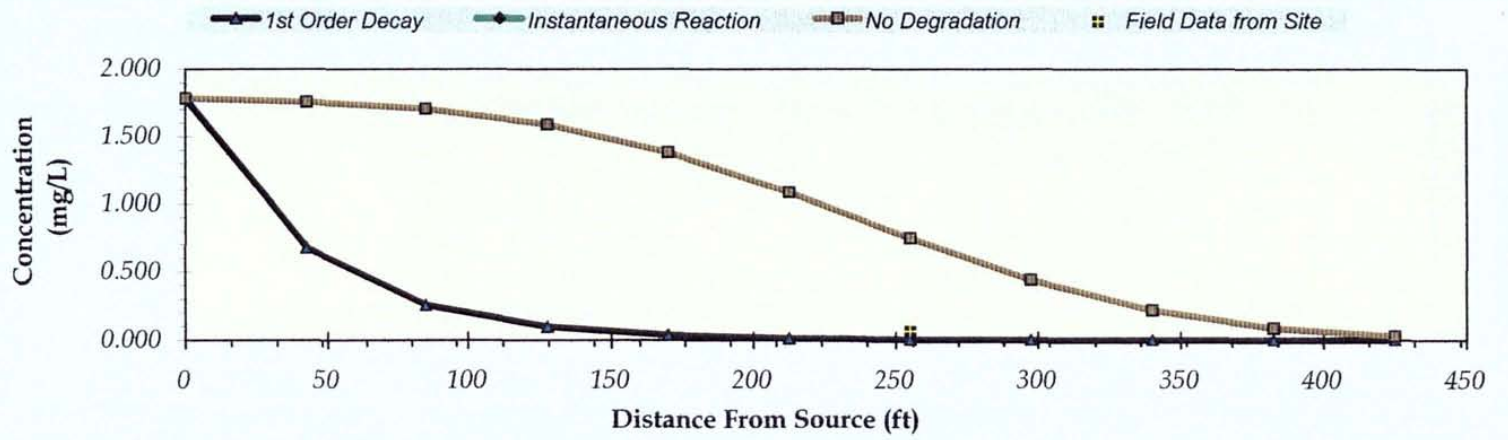
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ACENAPHTHENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	1.785	1.760	1.708	1.591	1.383	1.087	0.749	0.442	0.219	0.090	0.030
1st Order Decay	1.785	0.679	0.258	0.098	0.037	0.014	0.005	0.002	0.001	0.000	0.000
Inst. Reaction	1.785	1.760	1.708	1.591	1.383	1.087	0.749	0.442	0.219	0.090	0.030
Field Data from Site							0.065				



Calculate Animation

Time: 6.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Anthracene

Data Input Instructions:

115 / ↑ or / 0.02 → 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

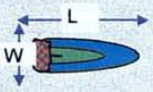
Retardation Factor*	R	39.3	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	12600	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	2.8E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	2.52	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	21	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

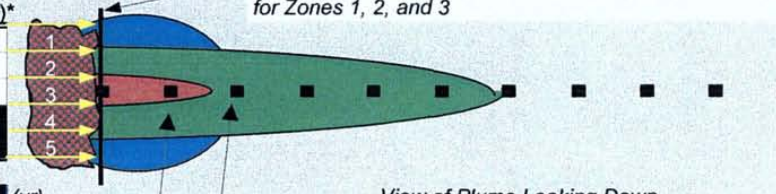
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.339
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.001					
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

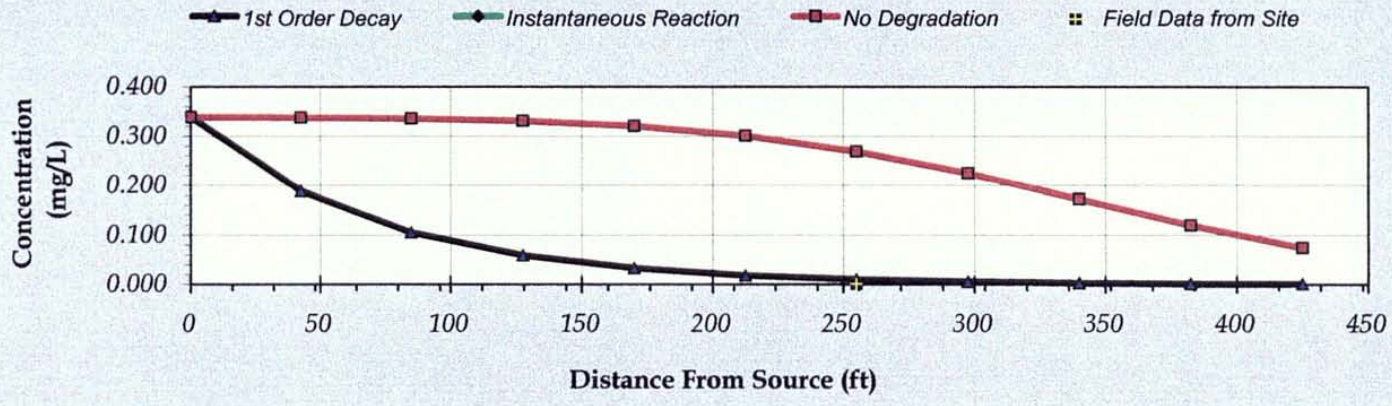
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ANTHRACENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.339	0.338	0.336	0.332	0.321	0.301	0.269	0.225	0.173	0.120	0.074
1st Order Decay	0.339	0.189	0.106	0.059	0.033	0.018	0.010	0.006	0.003	0.002	0.001
Inst. Reaction	0.339	0.338	0.336	0.332	0.321	0.301	0.269	0.225	0.173	0.120	0.074
Field Data from Site							0.001				



Calculate Animation

Time: 21.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade / North Area — Ethylbenzene

Data Input Instructions:
115 / ↑ or / 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	640.9	*(ft/yr)*
or		↑ or	
Hydraulic Conductivity	*K*	3.7E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.0063	*(ft/ft)*
Porosity	*n*	0.375	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	16.6	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		↑ or	
Estimated Plume Length	*Lp*	425	*(ft)*

3. ADSORPTION

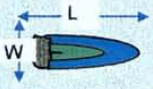
Retardation Factor*	*R*	3.1	*(-)*
or		↑ or	
Soil Bulk Density	*rho*	1.325	*(kg/l)*
Partition Coefficient	*Koc*	676	*(L/kg)*
FractionOrganicCarbon	*foc*	8.60E-04	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	1.1E+0	*(per yr)*
or		↑ or	
Solute Half-Life	*t-half*	0.62	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	425	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	4	*(yr)*



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 *(ft)*

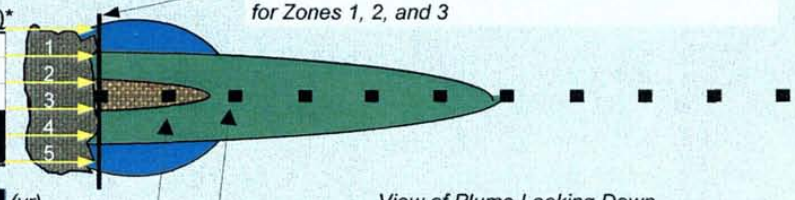
Source Zones:

	Width* (ft)	Conc. (mg/L)*
1		
2		
3	175	0.292
4	0	0
5	0	0

Source Decay (see Help):

SourceHalflife*	Infinite	*(yr)*
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	*(Kg)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.008
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

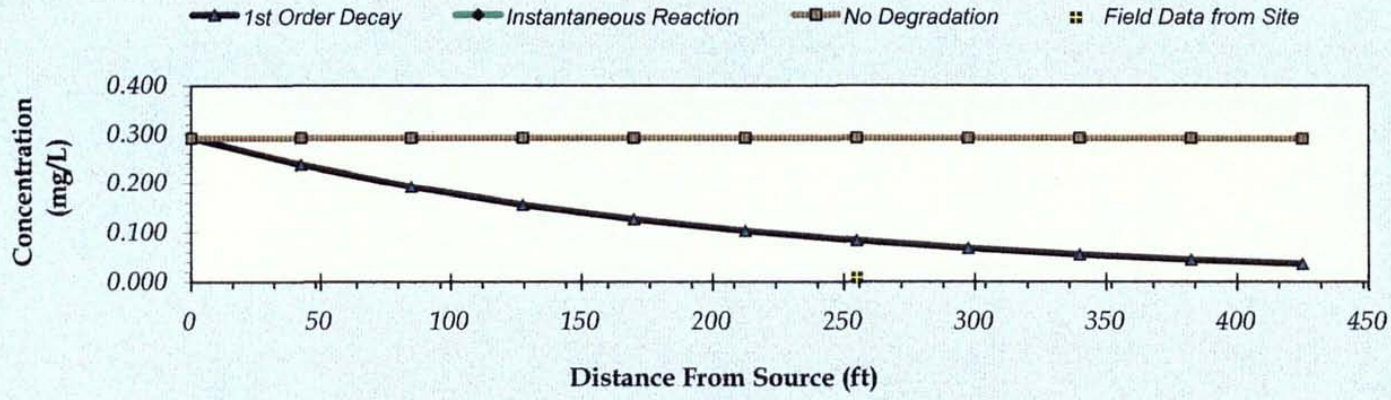
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ETHYLBENZENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.291	0.290
1st Order Decay	0.292	0.237	0.192	0.156	0.126	0.103	0.083	0.067	0.055	0.044	0.036
Inst. Reaction	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.292	0.291	0.290
Field Data from Site							0.008				



Calculate Animation

Time: 4.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Benzene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

Retardation Factor*	R	1.2	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	64.6	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	3.5E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	2.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	2	(yr)

6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

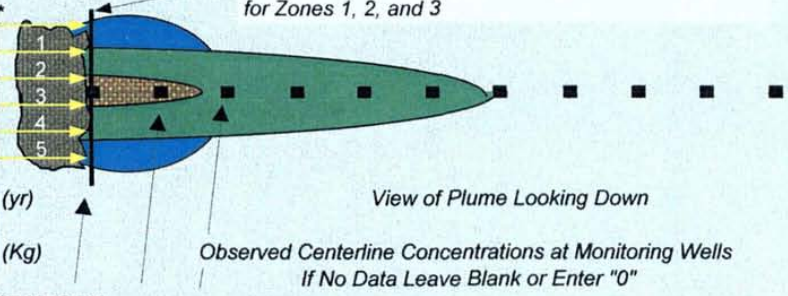
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	3.799
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.006
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

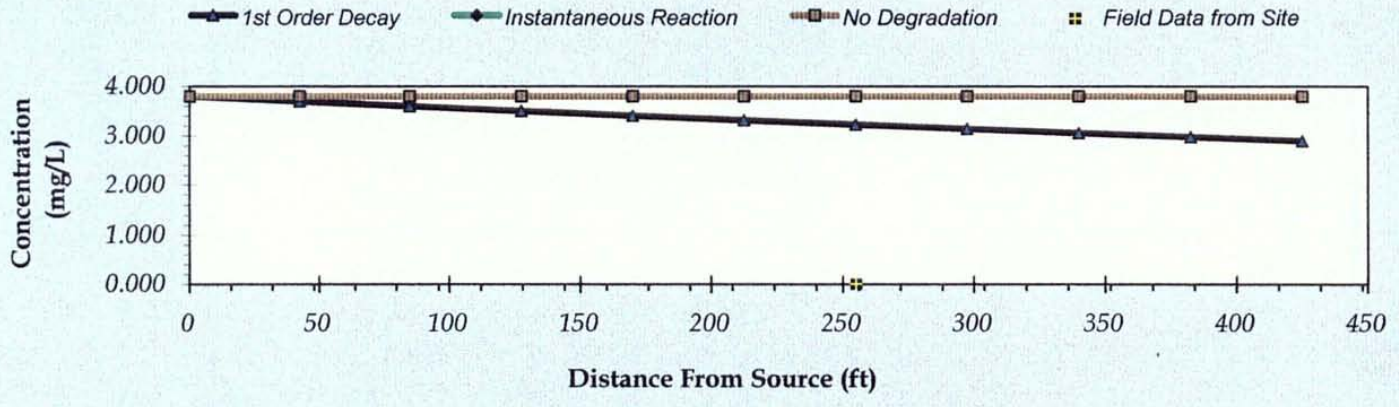
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED BENZENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

TYPE OF MODEL	Distance from Source (ft) 0	43	85	128	170	213	255	298	340	383	425
No Degradation	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.798
1st Order Decay	3.799	3.697	3.598	3.501	3.407	3.316	3.227	3.140	3.056	2.974	2.894
Inst. Reaction	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.799	3.798
Field Data from Site							0.006				



Calculate Animation

Time: 2.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Flourene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

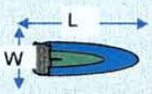
Retardation Factor*	R	25.1	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	7940	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	2.1E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.33	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	3	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

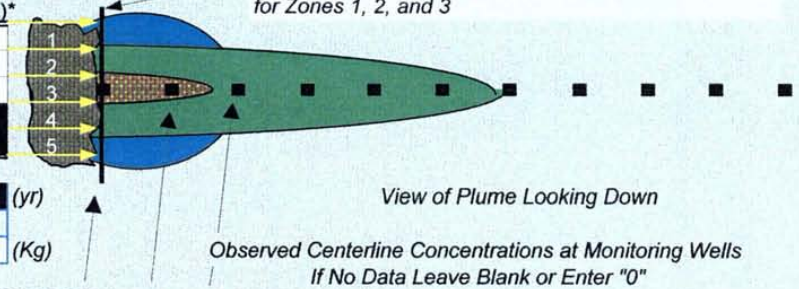
Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
175	0.881	3
0	0	4
0	0	5

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.043				
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

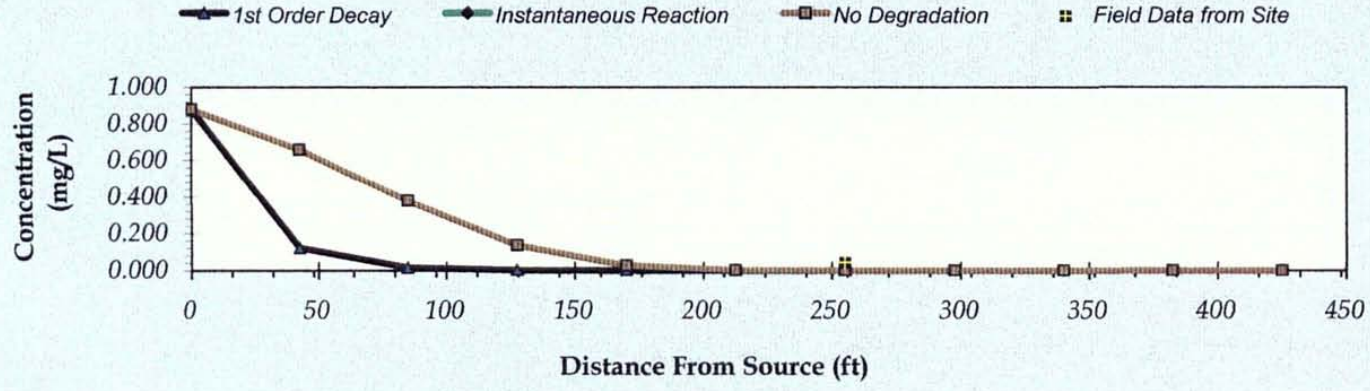
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED FLOURENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.881	0.661	0.382	0.137	0.028	0.003	0.000	0.000	0.000	0.000	0.000
1st Order Decay	0.881	0.122	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.881	0.661	0.382	0.137	0.028	0.003	0.000	0.000	0.000	0.000	0.000
Field Data from Site							0.043				



Calculate Animation

Time: 3.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Naphthalene

Data Input Instructions:

115 ↑ or 0.02 → 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

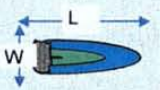
Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.8E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.71	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	6	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

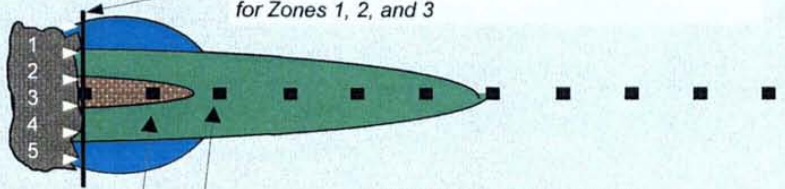
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	12.73
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	1.6
298	
340	
383	
425	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

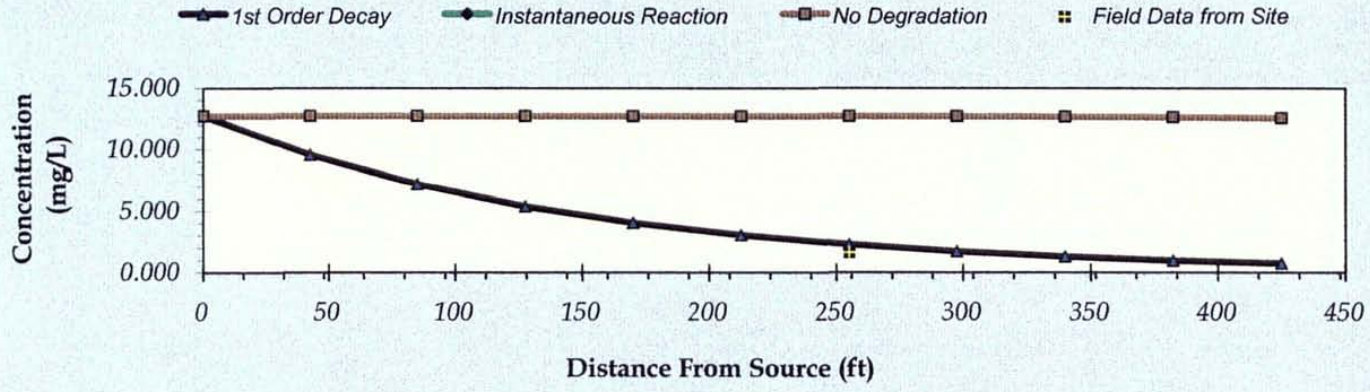
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	12.730	12.730	12.730	12.730	12.729	12.727	12.723	12.713	12.691	12.646	12.559
1st Order Decay	12.730	9.560	7.179	5.391	4.048	3.040	2.283	1.714	1.287	0.967	0.726
Inst. Reaction	12.730	12.730	12.730	12.730	12.729	12.727	12.723	12.713	12.691	12.646	12.559
Field Data from Site							1.600				



Calculate Animation

Time: 6.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Phenanthrene

Data Input Instructions:

115 / ↑ or / 0.02 → 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

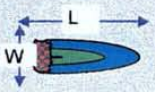
Retardation Factor*	R	39.3	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	12600	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.3E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	1.10	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*		425	(ft)
Modeled Area Width*		0	(ft)
Simulation Time*		11	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

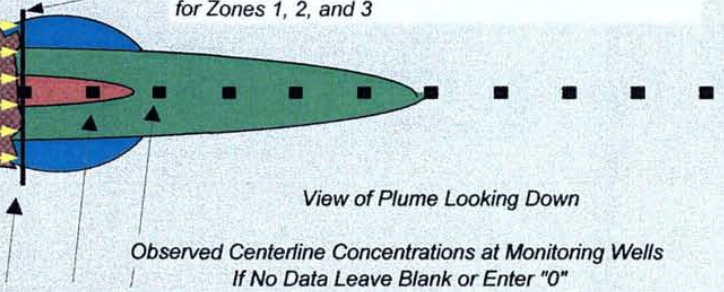
Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
175	0.598	3
0	0	4
0	0	5

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.026				
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

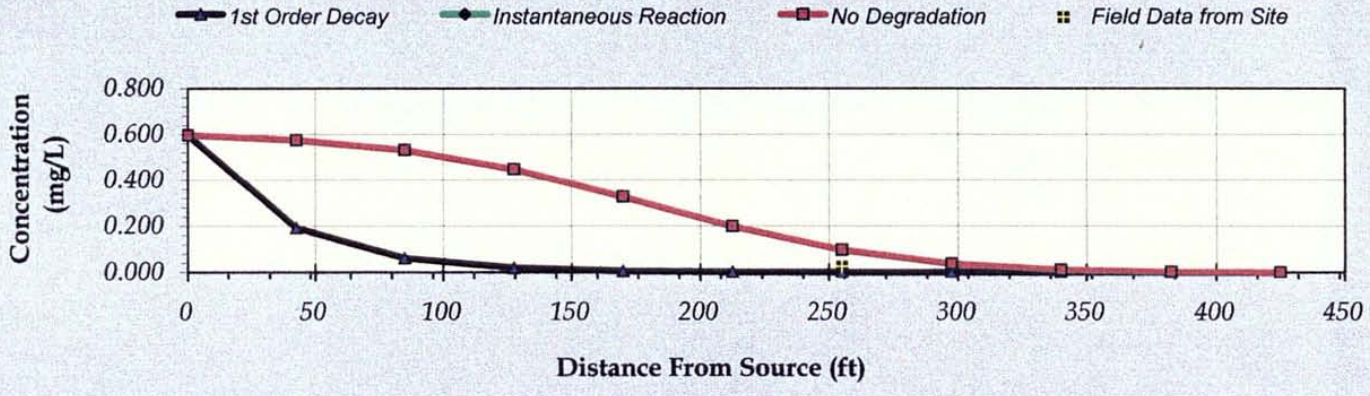
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED PHENANTHRENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.598	0.575	0.532	0.448	0.328	0.200	0.098	0.038	0.011	0.003	0.000
1st Order Decay	0.598	0.192	0.062	0.020	0.006	0.002	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	0.598	0.575	0.532	0.448	0.328	0.200	0.098	0.038	0.011	0.003	0.000
Field Data from Site							0.026				



Calculate Animation

Time: 11.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Pyrene

Data Input Instructions:

115 / ↑ or / 0.02 → 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	640.9	*(ft/yr)*
or		↑ or	
Hydraulic Conductivity	*K*	3.7E-02	*(cm/sec)*
Hydraulic Gradient	*i*	0.0063	*(ft/ft)*
Porosity	*n*	0.375	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	16.6	*(ft)*
Transverse Dispersivity*	*alpha y*	0.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		↑ or	
Estimated Plume Length	*Lp*	425	*(ft)*

3. ADSORPTION

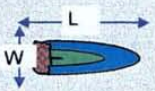
Retardation Factor*	*R*	116.5	*(-)*
or		↑ or	
Soil Bulk Density	*rho*	1.325	*(kg/l)*
Partition Coefficient	*Koc*	38000	*(L/kg)*
FractionOrganicCarbon	*foc*	8.60E-04	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	6.7E-2	*(per yr)*
or		↑ or	
Solute Half-Life	*t-half*	10.40	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	425	*(ft)*
Modeled Area Width*	0	*(ft)*
Simulation Time*	60	*(yr)*



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 *(ft)*

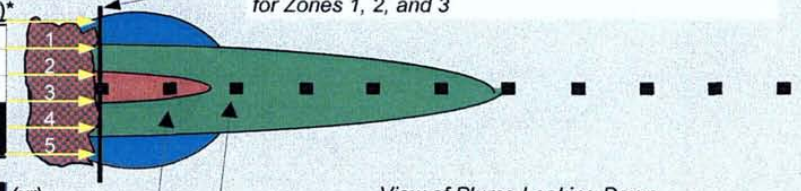
Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
175	0.109	3
0	0	4
0	0	5

Source Decay (see Help):

SourceHalflife*	Infinite	*(yr)*
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	*(Kg)*

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.001				
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

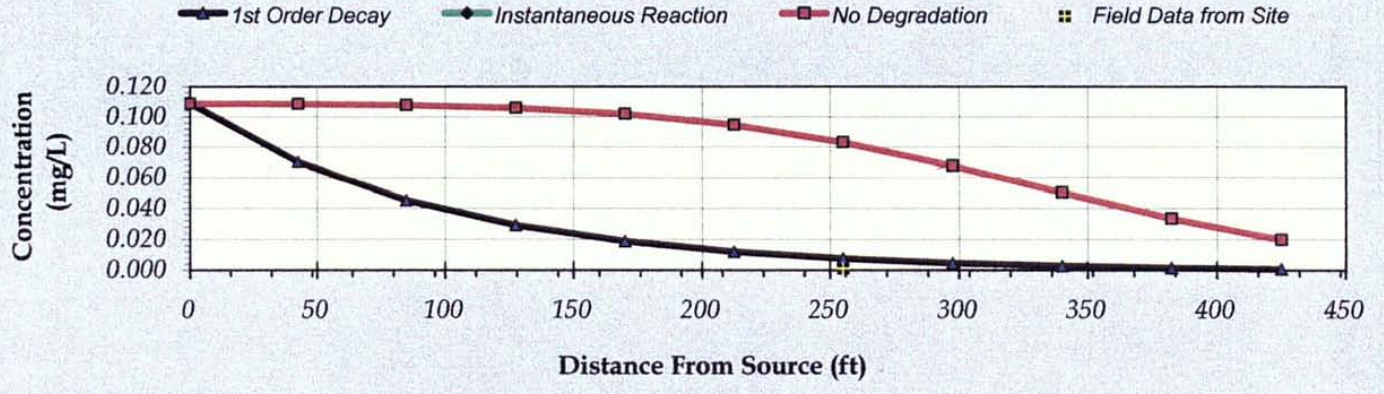
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED PYRENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.109	0.109	0.108	0.106	0.102	0.095	0.083	0.068	0.050	0.034	0.020
1st Order Decay	0.109	0.070	0.045	0.029	0.019	0.012	0.008	0.005	0.003	0.002	0.001
Inst. Reaction	0.109	0.109	0.108	0.106	0.102	0.095	0.083	0.068	0.050	0.034	0.020
Field Data from Site							0.001				



Calculate Animation

Time: 60.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Toluene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

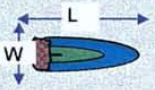
Retardation Factor*	R	1.8	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	257	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.7E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.08	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	1	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

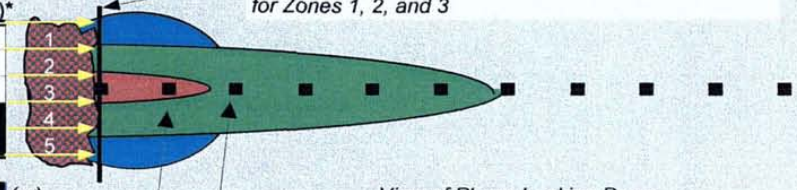
Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
175	1.041	3
0	0	4
0	0	5

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
43	
85	
128	
170	
213	
255	.005
298	
340	
383	
425	

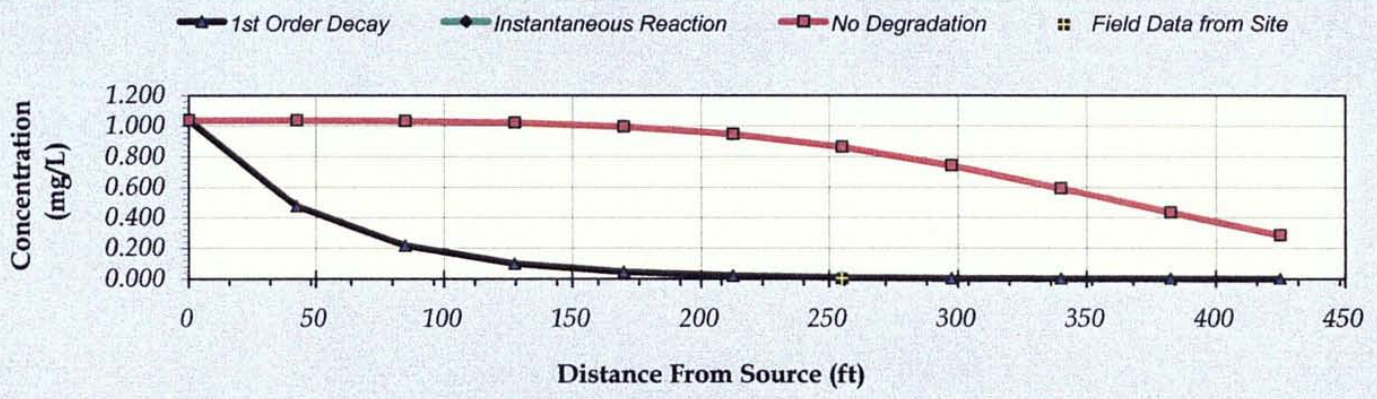
8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE	RUN ARRAY	Help	Recalculate This Sheet
View Output	View Output	Paste Example Dataset	
		Restore Formulas for Vs, Dispersivities, R, lambda, other	

DISSOLVED TOLUENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	1.041	1.039	1.035	1.024	0.998	0.949	0.865	0.745	0.596	0.435	0.287
1st Order Decay	1.041	0.476	0.217	0.099	0.045	0.021	0.009	0.004	0.002	0.001	0.000
Inst. Reaction	1.041	1.039	1.035	1.024	0.998	0.949	0.865	0.745	0.596	0.435	0.287
Field Data from Site							0.005				



Calculate Animation

Time: 1.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.3

South Cavalcade
North Area
Xylene

Data Input Instructions:

115 → 1. Enter value directly....or
or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	640.9	(ft/yr)
or		or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.0063	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

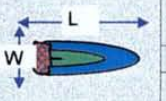
Retardation Factor*	R	3.1	(-)
or		or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	692	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1	(per yr)
or		or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	425	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	5	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

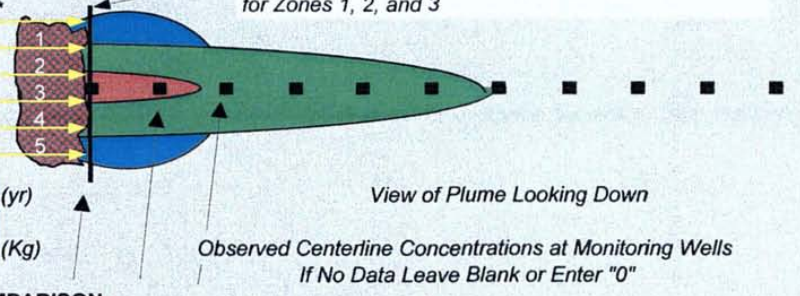
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	0.313
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)							.009					
Dist. from Source (ft)	0	43	85	128	170	213	255	298	340	383	425

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

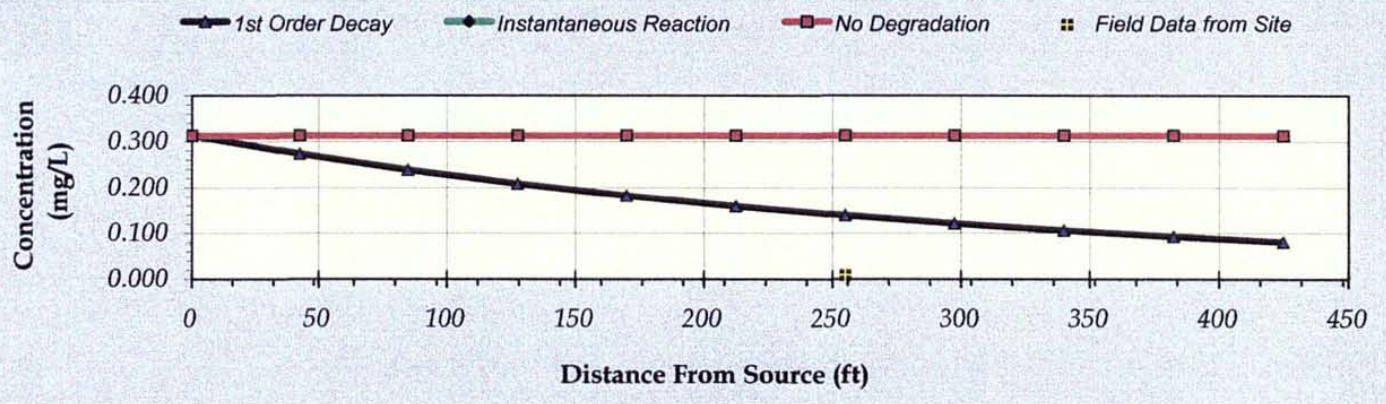
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED XYLENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	43	85	128	170	213	255	298	340	383	425
No Degradation	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313
1st Order Decay	0.313	0.273	0.239	0.208	0.182	0.159	0.139	0.121	0.106	0.093	0.081
Inst. Reaction	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313	0.313
Field Data from Site							0.009				



Calculate Animation

Time: 5.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Ethylbenzene

Data Input Instructions:

115 or 0.02 → 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	49.7	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.0072	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

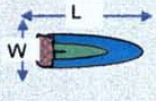
Retardation Factor*	R	3.1	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	676	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.1E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.62	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	5	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

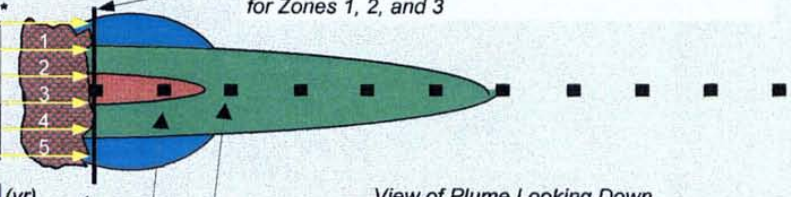
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	0.292
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

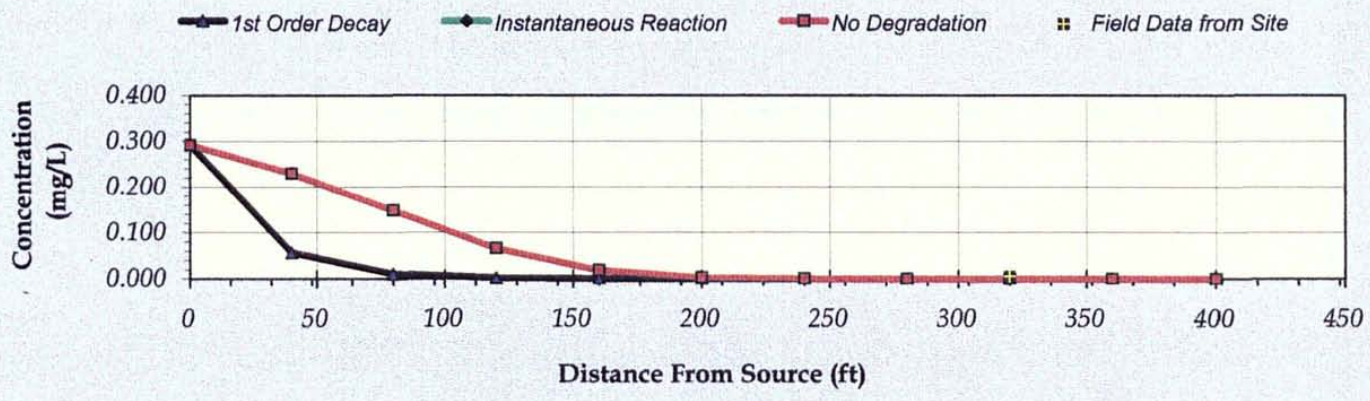
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED ETHYLBENZENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - SOUTH AREA

TYPE OF MODEL	Distance from Source (ft) 0	40	80	120	160	200	240	280	320	360	400
No Degradation	0.292	0.230	0.149	0.067	0.019	0.003	0.000	0.000	0.000	0.000	0.000
1st Order Decay	0.292	0.057	0.011	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.292	0.230	0.149	0.067	0.019	0.003	0.000	0.000	0.000	0.000	0.000
Field Data from Site									0.005		



Calculate Animation

Time: 5.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.3

South Cavalcade
South Area
Benzene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	49.7	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.0072	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

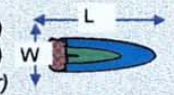
Retardation Factor*	R	1.2	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	64.6	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	3.5E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	2.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	16	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

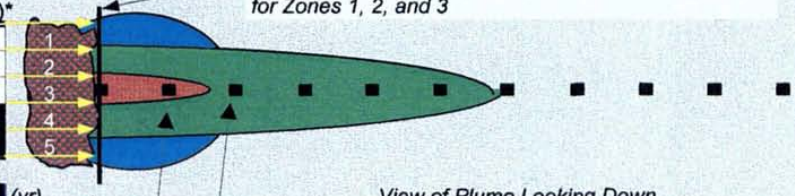
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	3.799
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)									.005			
Dist. from Source (ft)	0	40	80	120	160	200	240	280	320	360	400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

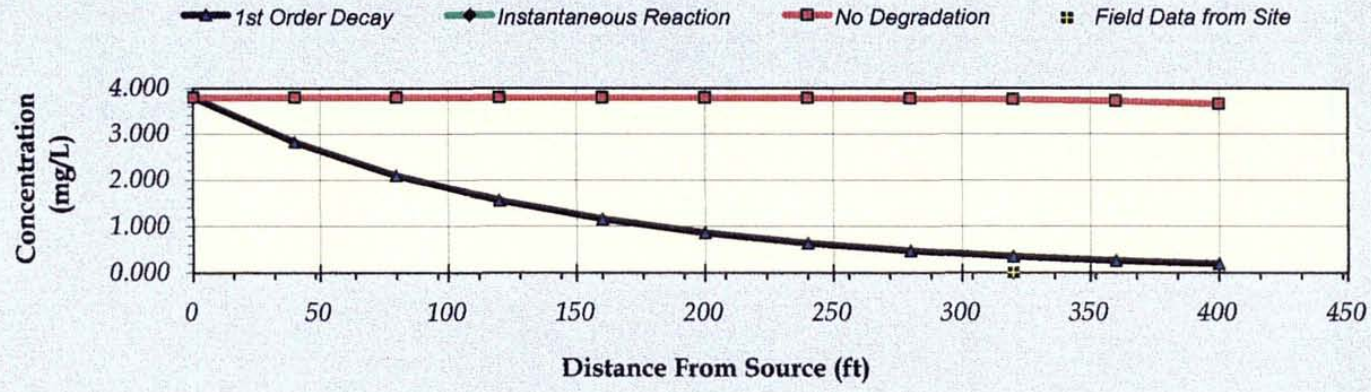
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED BENZENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - SOUTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	3.799	3.799	3.799	3.799	3.798	3.796	3.791	3.781	3.760	3.722	3.656
1st Order Decay	3.799	2.822	2.097	1.558	1.157	0.860	0.639	0.474	0.352	0.262	0.194
Inst. Reaction	3.799	3.799	3.799	3.799	3.798	3.796	3.791	3.781	3.760	3.722	3.656
Field Data from Site									0.005		



Calculate Animation

Time: 16.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Naphthalene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	49.7	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.0072	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.8E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.71	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	9	(yr)

6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

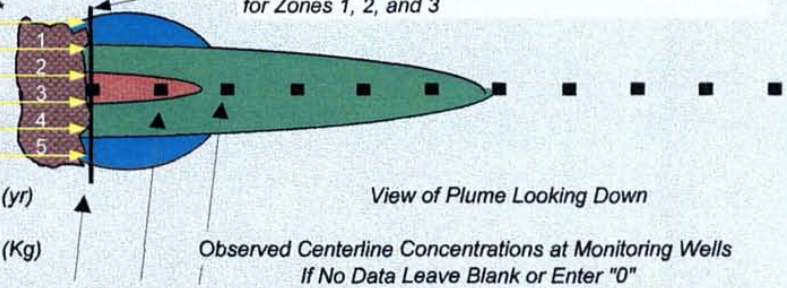
Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
200	12.73	3
0	0	4
0	0	5

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.024
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

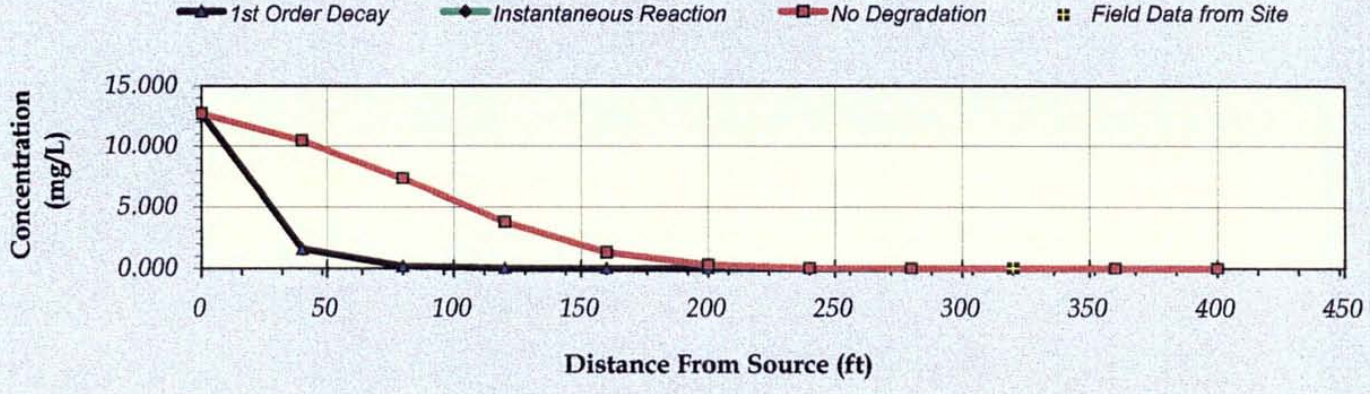
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - SOUTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	12.730	10.474	7.362	3.791	1.324	0.298	0.042	0.004	0.000	0.000	0.000
1st Order Decay	12.730	1.595	0.200	0.025	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	12.730	10.474	7.362	3.791	1.324	0.298	0.042	0.004	0.000	0.000	0.000
Field Data from Site									0.024		



Calculate Animation

Time: 9.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Xylene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	49.7	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.0072	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

Retardation Factor*	R	3.1	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	692	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	8	(yr)

6. SOURCE DATA

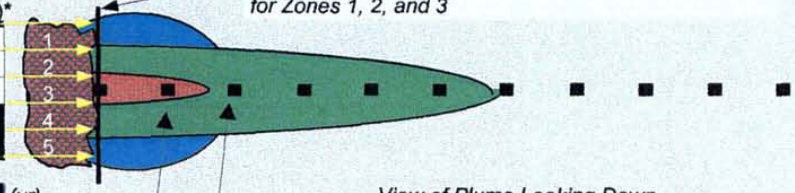
Source Thickness in Sat.Zone* 15 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
200	0.313
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)



Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

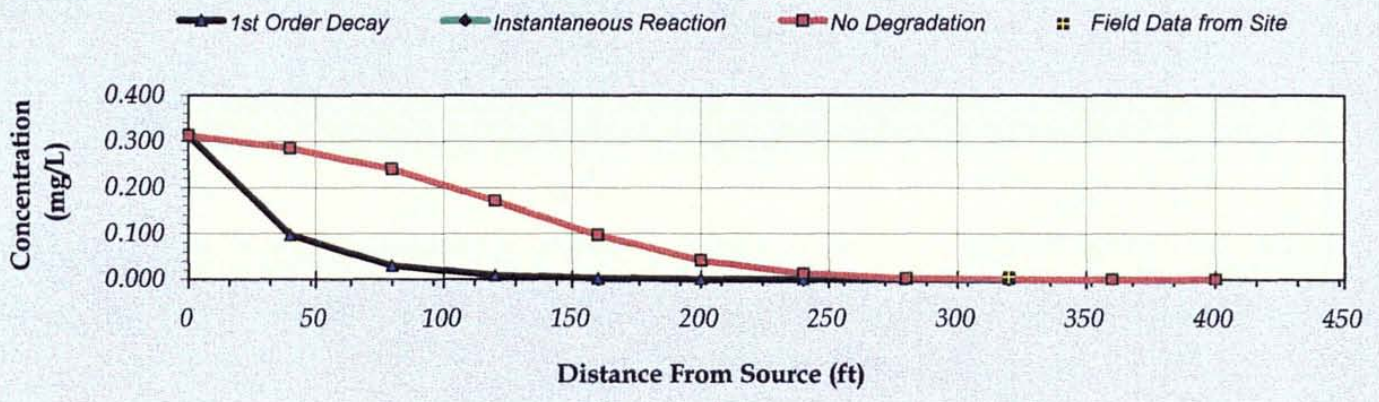
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED XYLENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - SOUTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	0.313	0.285	0.241	0.172	0.098	0.042	0.013	0.003	0.001	0.000	0.000
1st Order Decay	0.313	0.097	0.030	0.009	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.313	0.285	0.241	0.172	0.098	0.042	0.013	0.003	0.001	0.000	0.000
Field Data from Site									0.005		



Calculate Animation

Time: 8.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Toluene

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.
20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	49.7	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.0072	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	400	(ft)

3. ADSORPTION

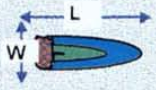
Retardation Factor*	R	1.8	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	257	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.7E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.08	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	400	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	1	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

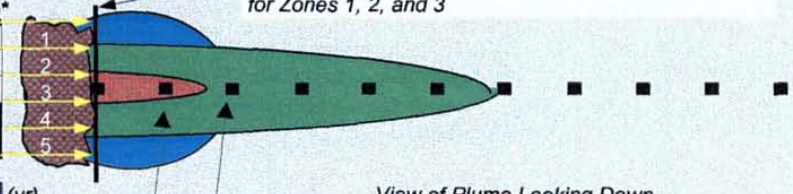
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	1.041
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
40	
80	
120	
160	
200	
240	
280	
320	.005
360	
400	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

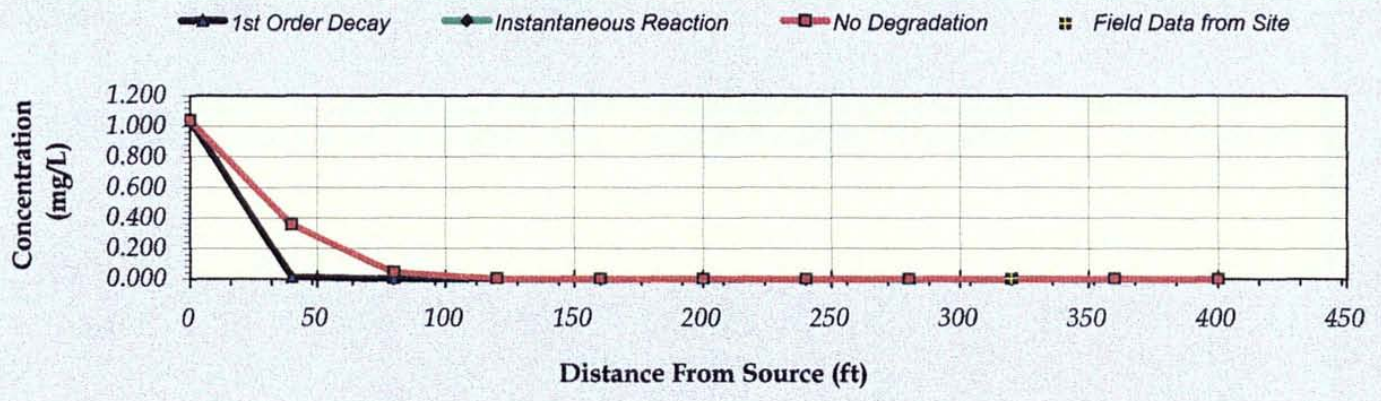
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED TOULENE CONCENTRATION (mg/l) - HYPOTHETICAL PUMPING SCENARIO - SOUTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	40	80	120	160	200	240	280	320	360	400
No Degradation	1.041	0.359	0.045	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	1.041	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	1.041	0.359	0.045	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site									0.005		



Calculate Animation

Time: 1.00 Years

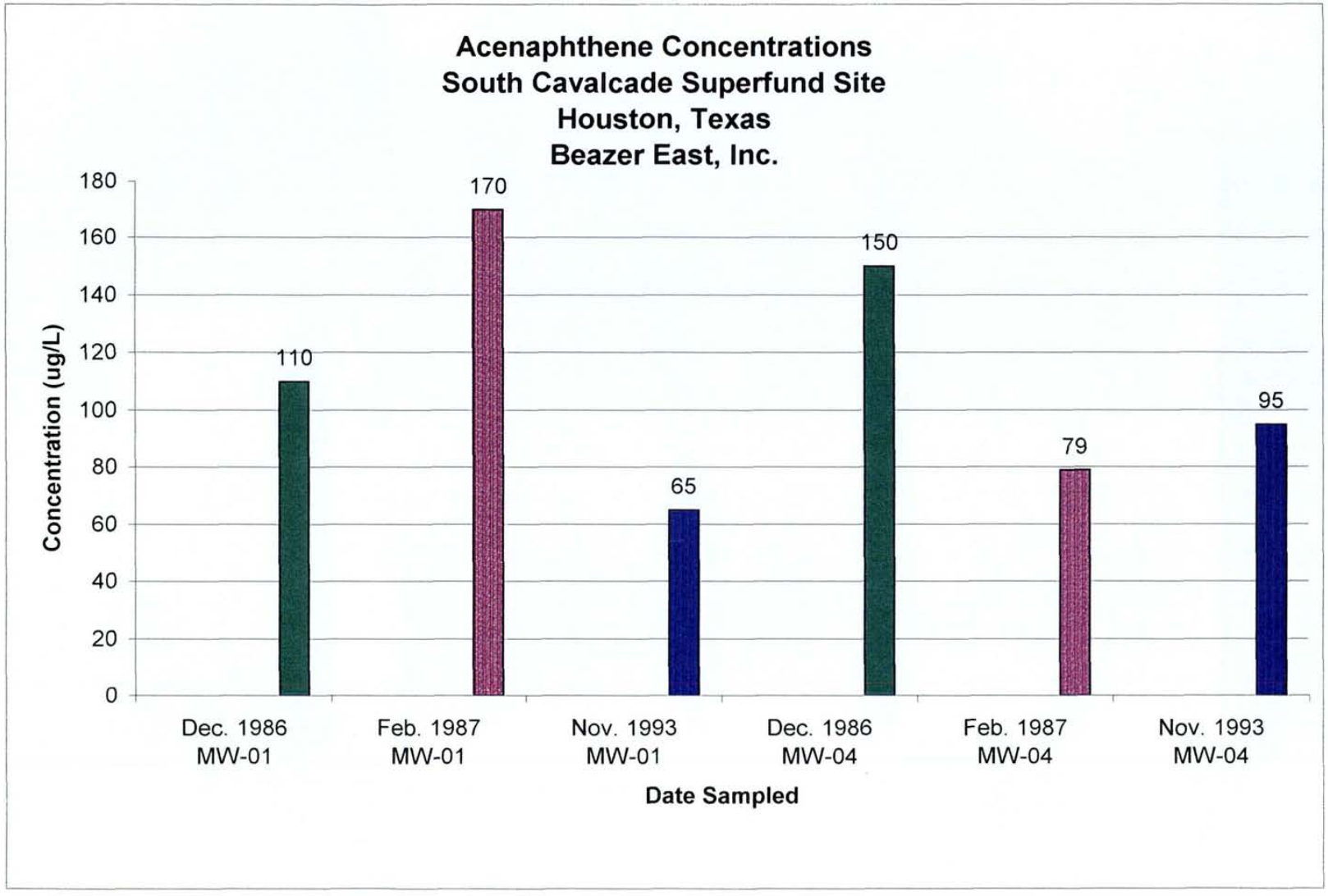
Return to Input

Recalculate This Sheet

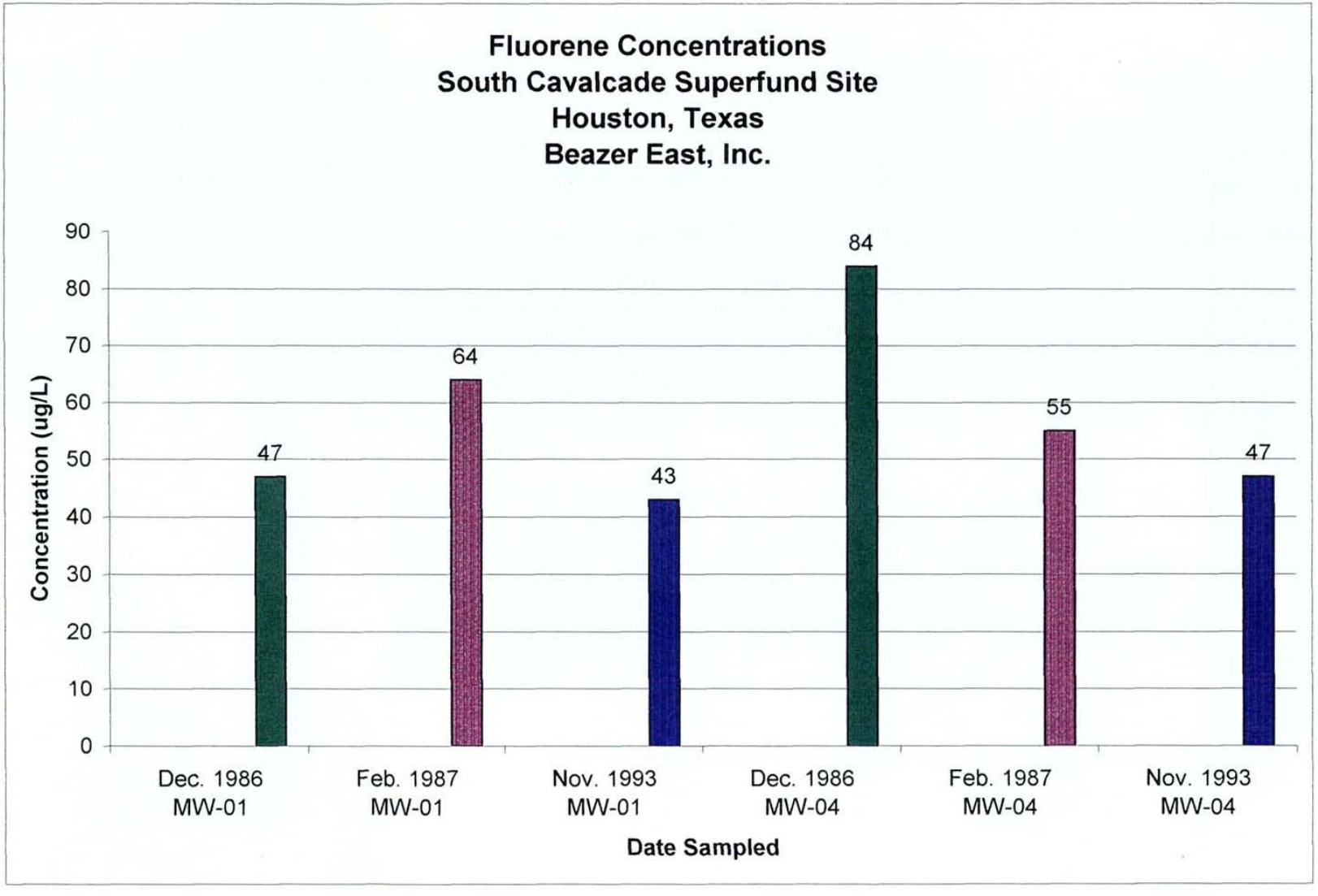
APPENDIX O

COMPARISON OF 1986-87 AND 1993 GROUNDWATER DATA

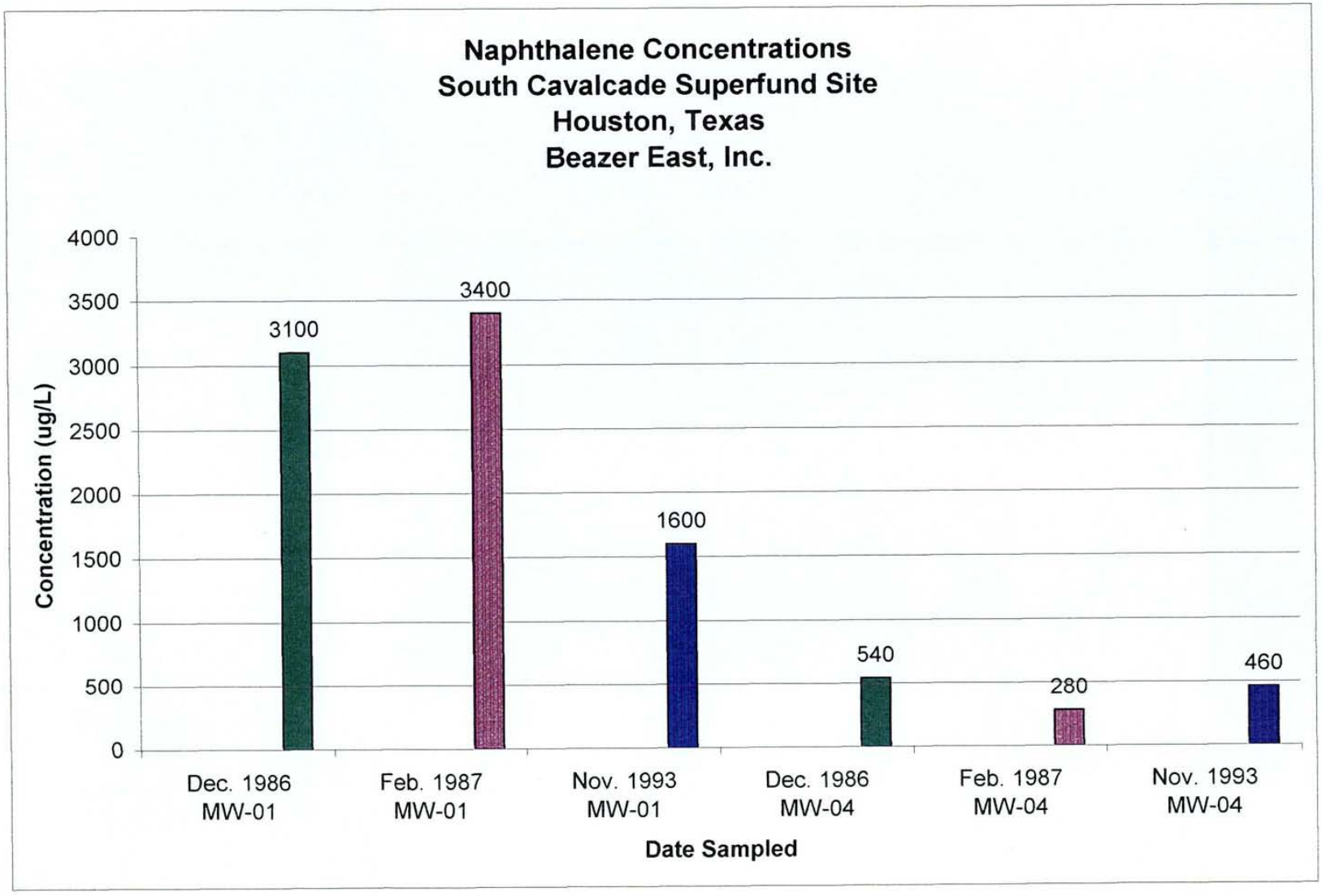
KEY ENVIRONMENTAL INCORPORATED



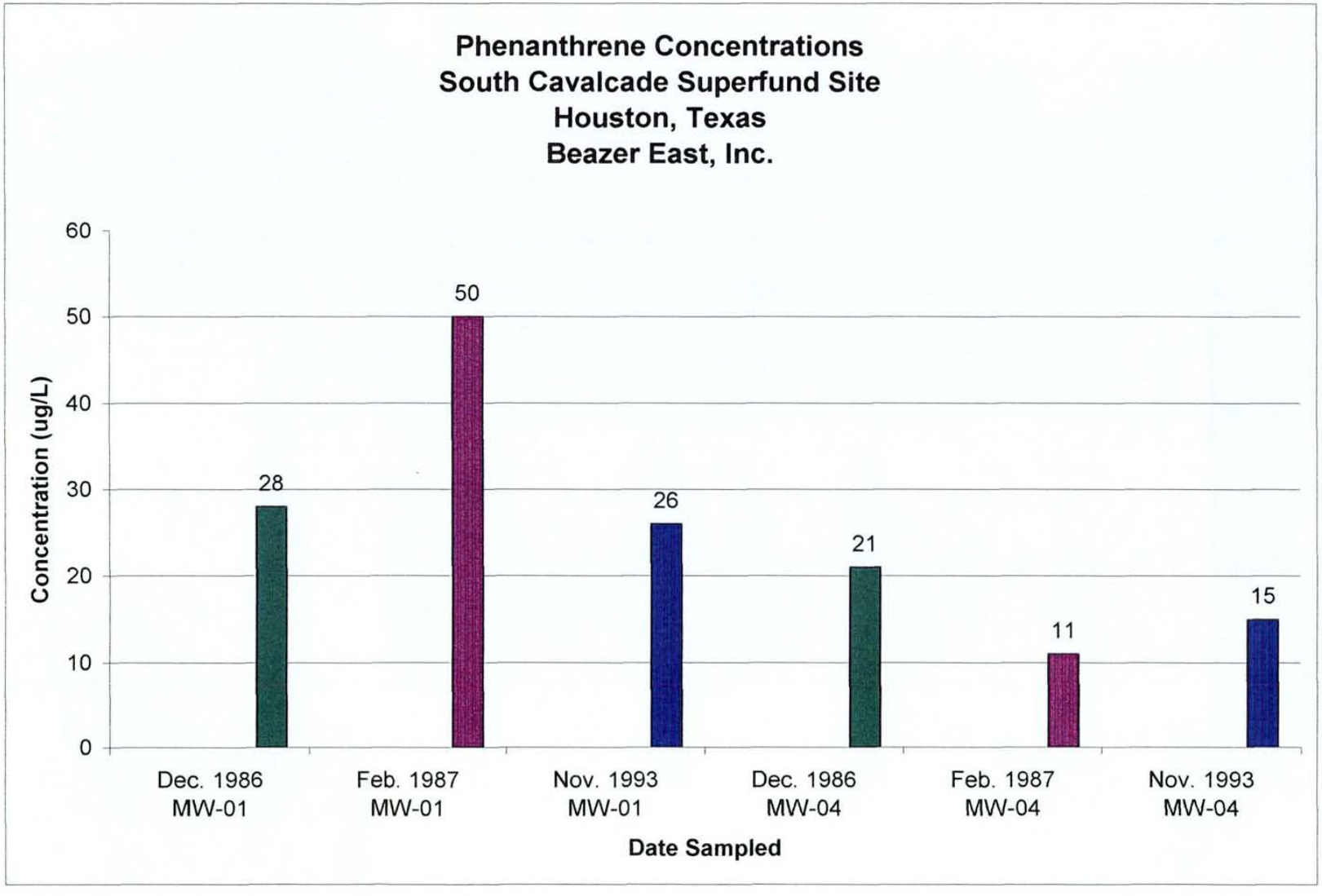
c:\vm\zub\acenaphthene Chart 1



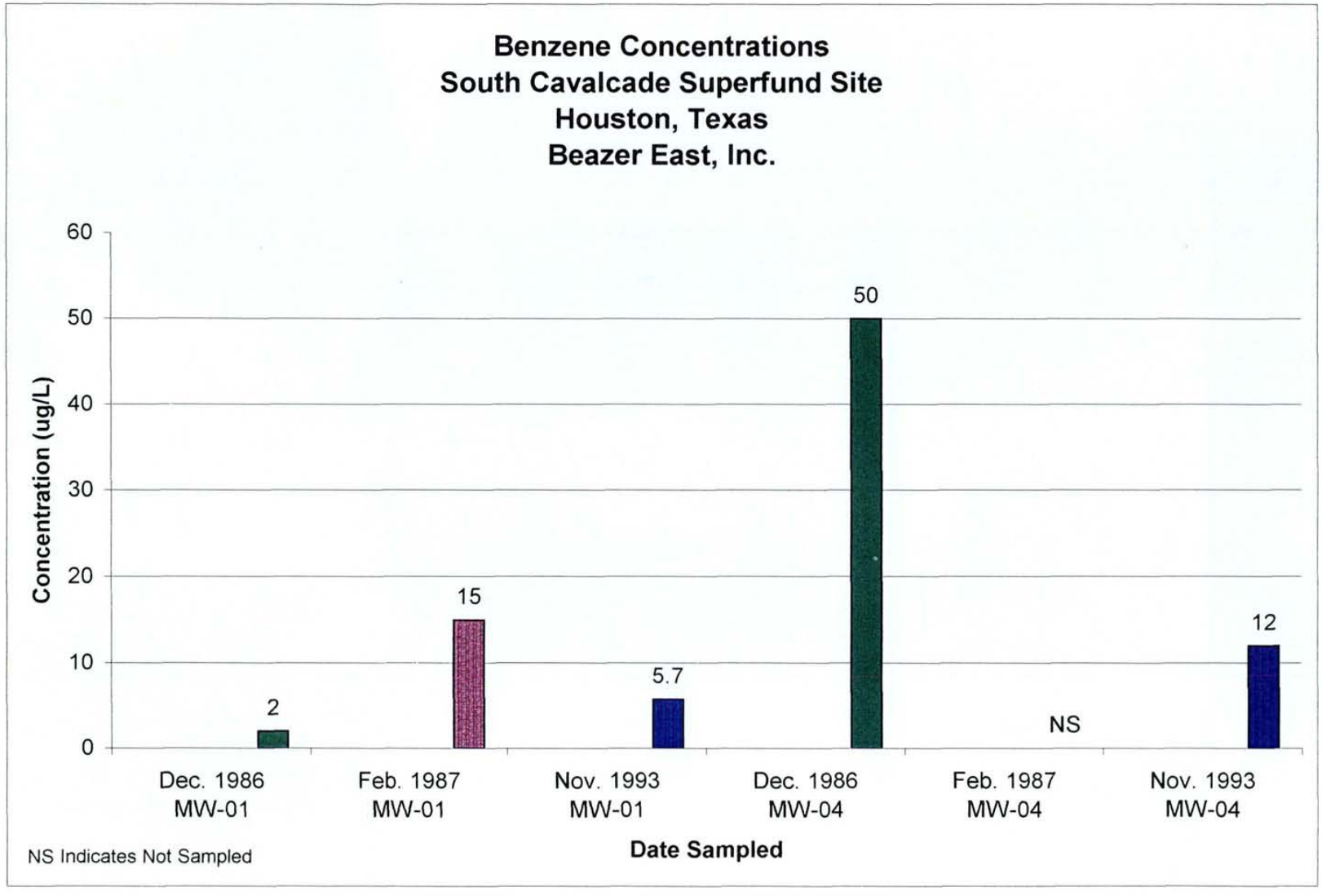
c:\vm\zub\fluorene Chart 1



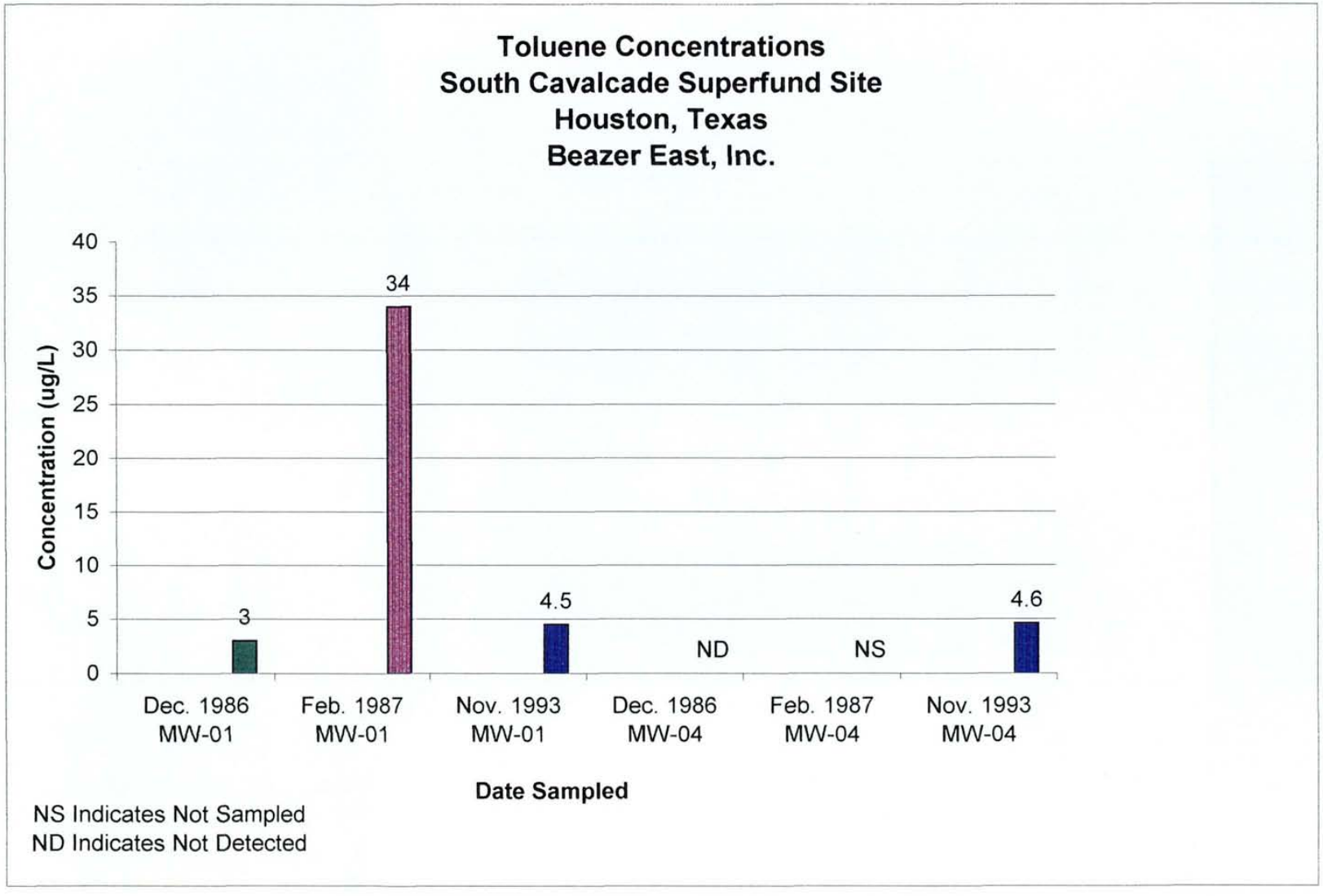
c:\vm\zub\naphthalene Chart 1



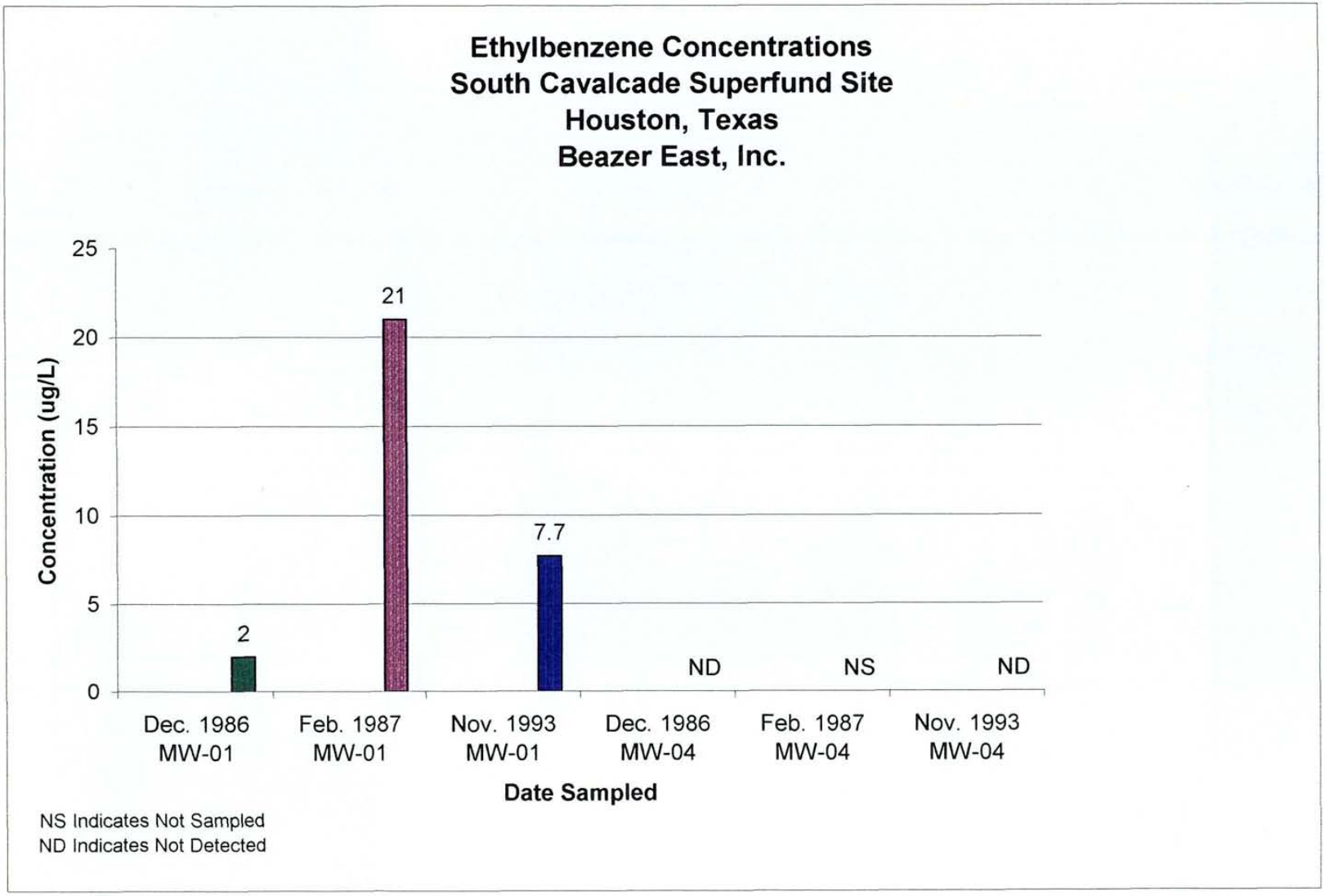
c:\vm\zub\phenanthrene Chart 1



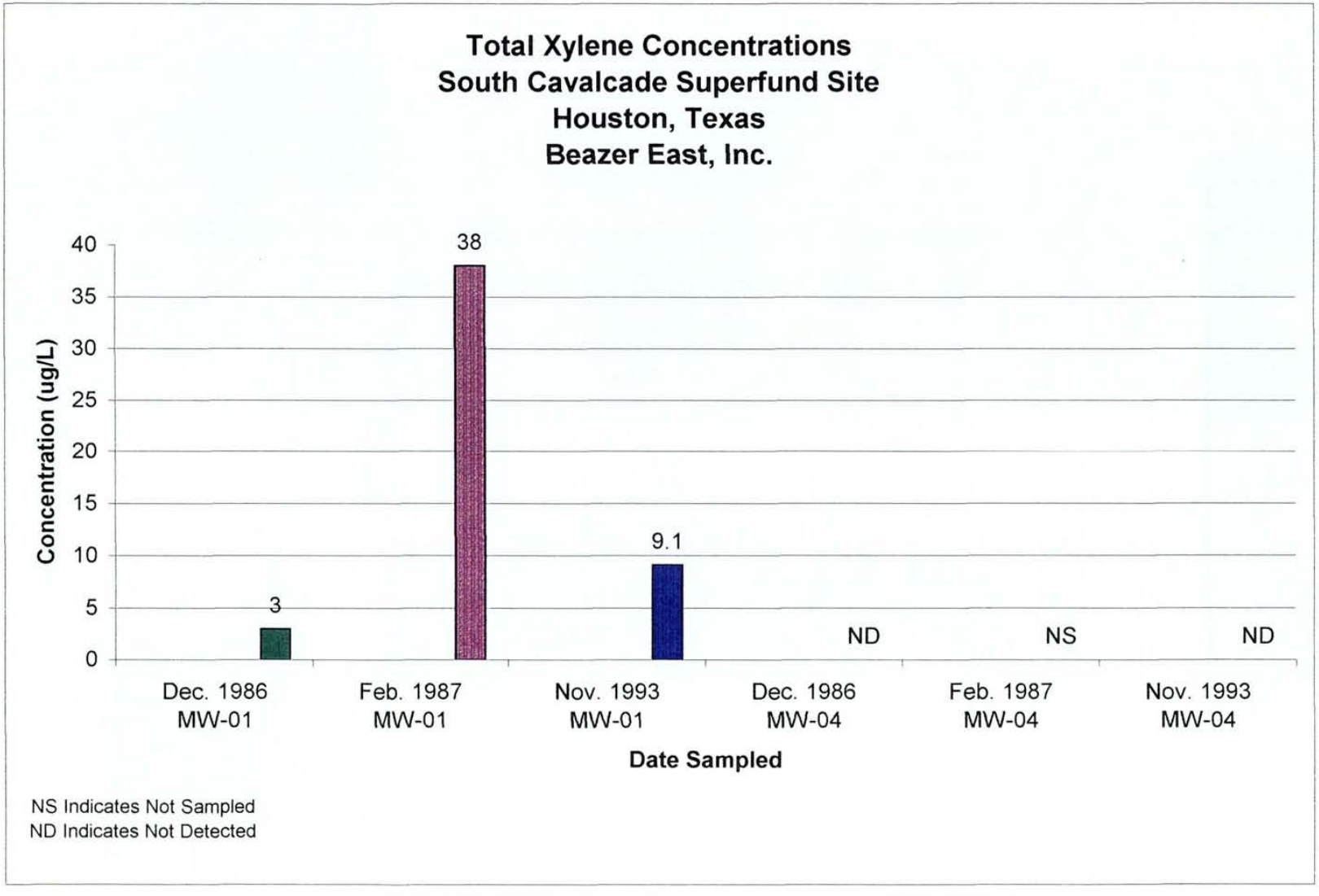
c:\vm\zub\benzene Chart 1



c:\vm\zub\toluene Chart 1



c:\vm\zub\ethylbenzene Chart 1

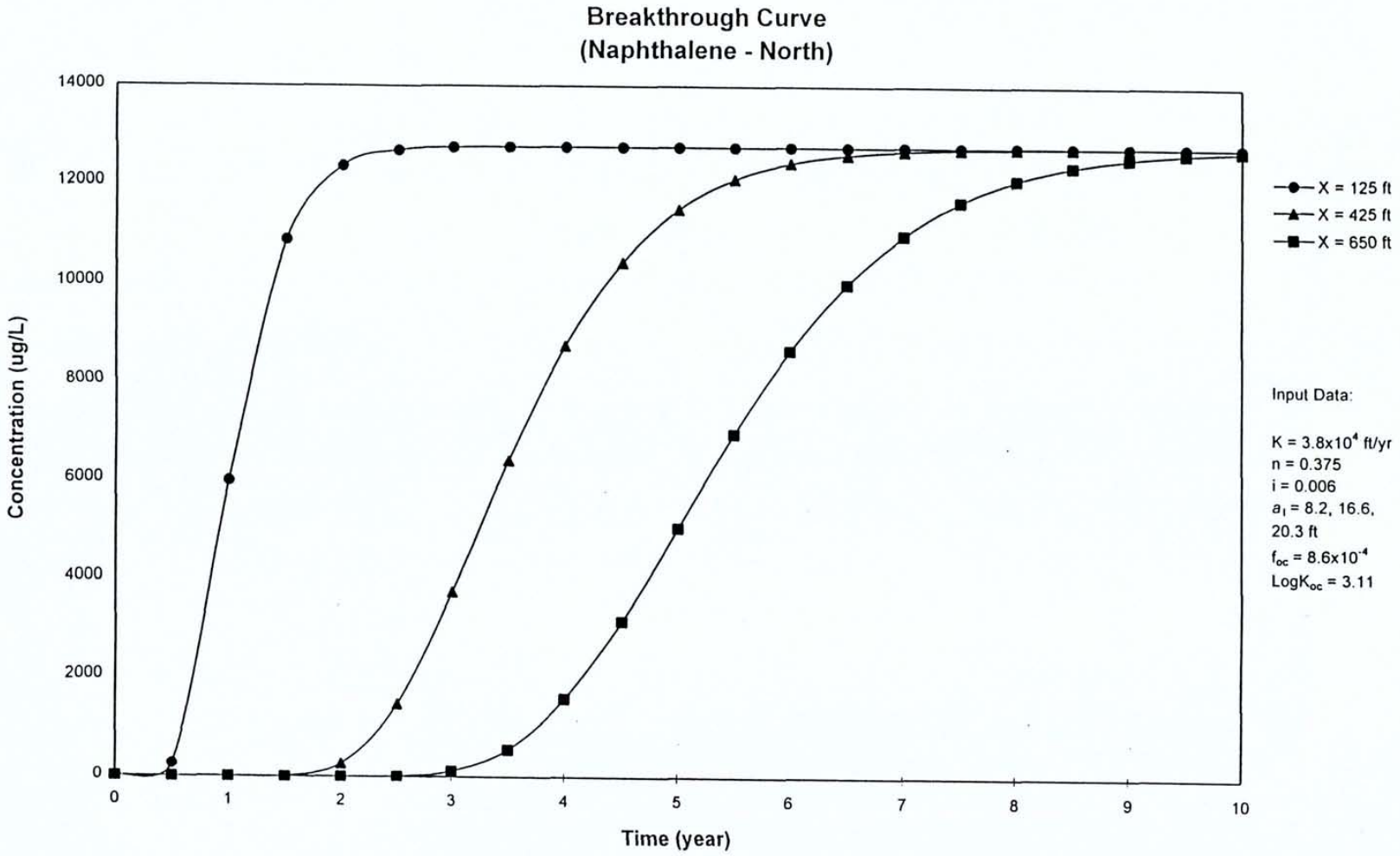


c:\vm\zub\total xylenes Chart 1

APPENDIX P

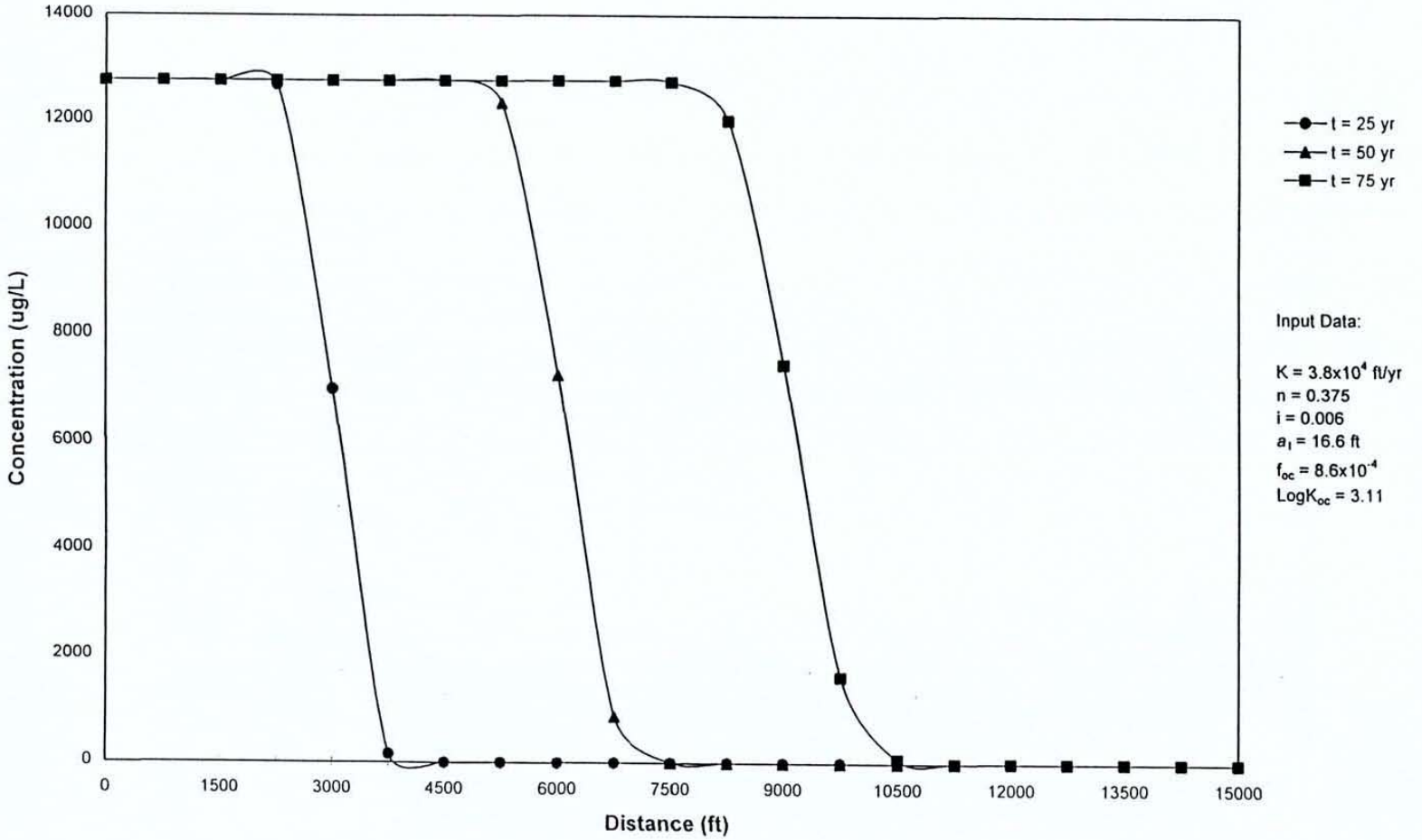
COMPARISON OF OGATA-BANKS AND BIOSCREEN SIMULATION RESULTS

KEY ENVIRONMENTAL INCORPORATED



c:\jrh\socav\118-11n.nat

Breakthrough Curve
(Naphthalene - North)



c:\jrh\socav\118-11n.nat

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Naphthalene

Data Input Instructions:

115 / ↑ or / 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	8.2	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

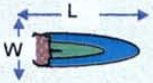
Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	0.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	210	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	1	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

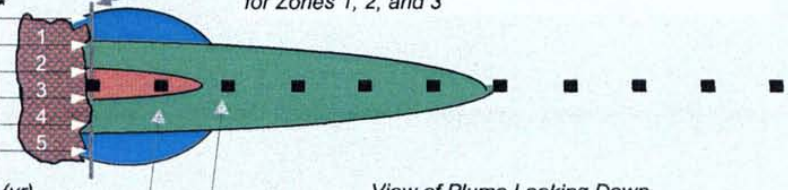
Source Zones:

Width* (ft)	Conc. (mg/L)*
175	12.73
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
21	
42	
63	
84	
105	
126	
147	
168	
189	
210	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

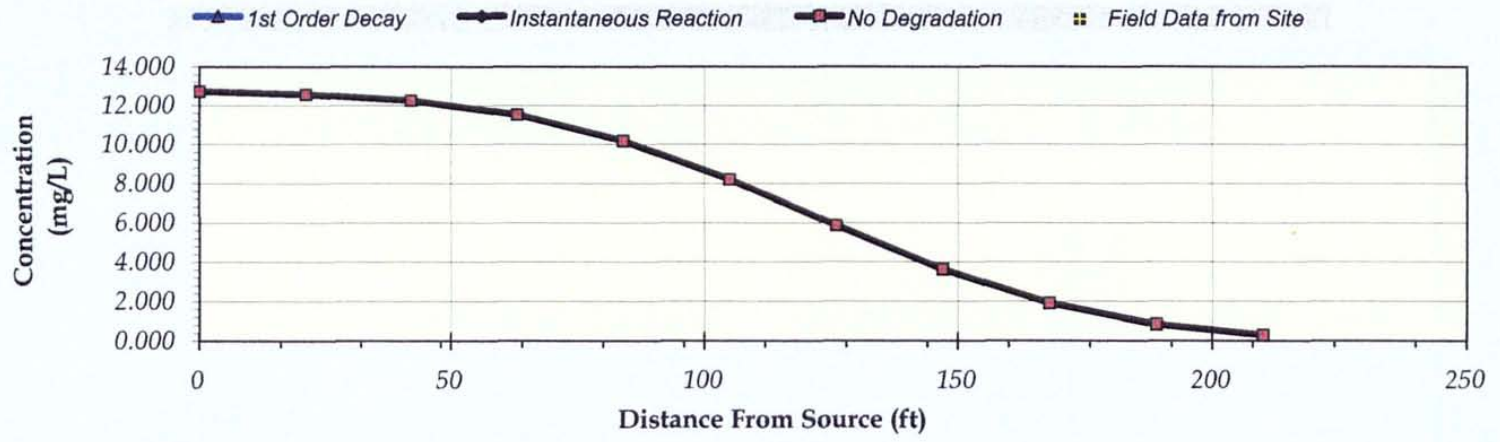
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - NORTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	21	42	63	84	105	126	147	168	189	210
No Degradation	12.730	12.575	12.254	11.523	10.184	8.208	5.863	3.623	1.900	0.834	0.303
1st Order Decay	12.730	12.575	12.254	11.523	10.184	8.208	5.863	3.623	1.900	0.834	0.303
Inst. Reaction	12.730	12.575	12.254	11.523	10.184	8.208	5.863	3.623	1.900	0.834	0.303
Field Data from Site											



Calculate Animation

Time: 1.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Naphthalene

Data Input Instructions:

115 / ↑ or / 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.6	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

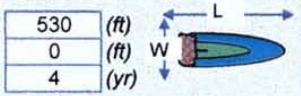
Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	0.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	530	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	4	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

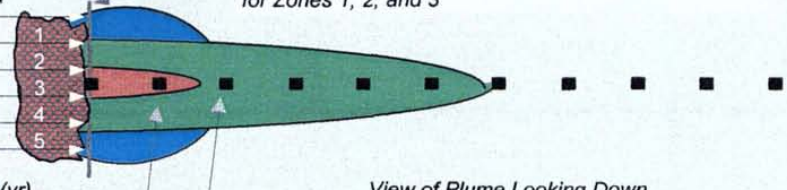
Source Zones:

Width* (ft)	Conc. (mg/L)*	
		1
		2
175	12.73	3
0	0	4
0	0	5

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
53	
106	
159	
212	
265	
318	
371	
424	
477	
530	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

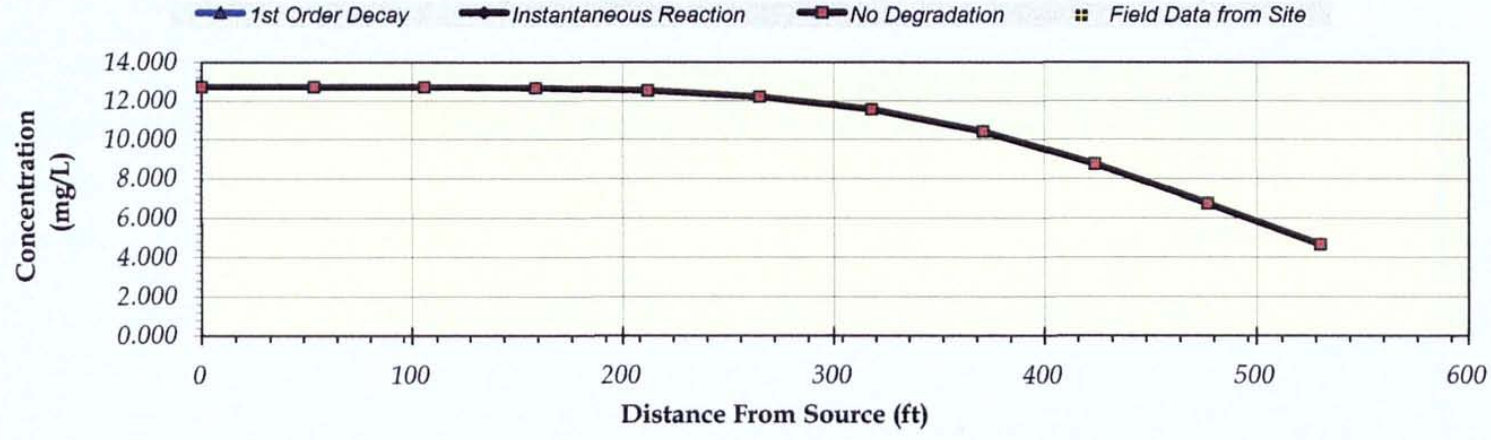
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	53	106	159	212	265	318	371	424	477	530
No Degradation	12.730	12.726	12.712	12.666	12.534	12.211	11.551	10.412	8.759	6.737	4.653
1st Order Decay	12.730	12.726	12.712	12.666	12.534	12.211	11.551	10.412	8.759	6.737	4.653
Inst. Reaction	12.730	12.726	12.712	12.666	12.534	12.211	11.551	10.412	8.759	6.737	4.653
Field Data from Site											



Calculate Animation

Time: 4.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
North Area
Naphthalene

Data Input Instructions:

115 / ↑ or / 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	598.2	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	3.7E-02	(cm/sec)
Hydraulic Gradient	i	0.00588	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	20.3	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

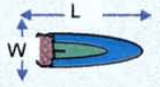
Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	0.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	810	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	6	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

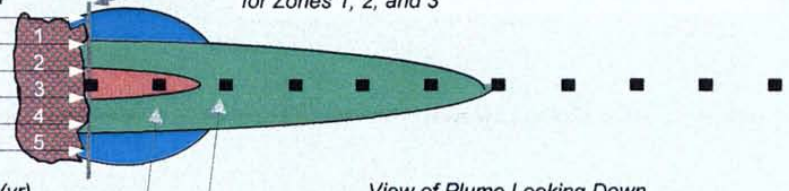
Source Zones:

	Width* (ft)	Conc. (mg/L)*
1		
2		
3	175	12.73
4	0	0
5	0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
81	
162	
243	
324	
405	
486	
567	
648	
729	
810	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

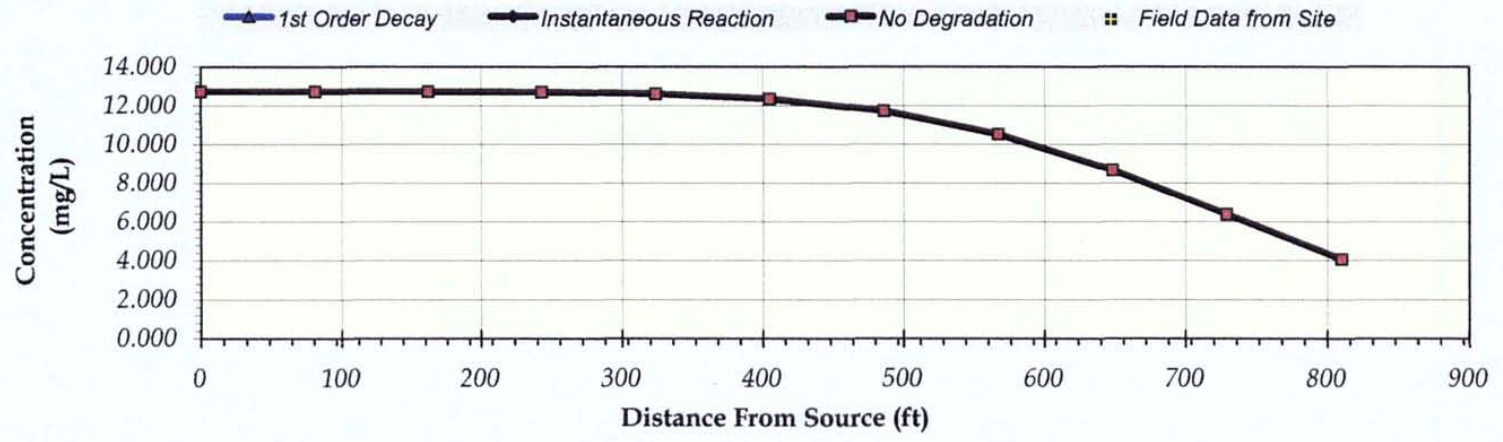
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - NORTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	81	162	243	324	405	486	567	648	729	810
No Degradation	12.730	12.729	12.724	12.700	12.612	12.352	11.730	10.533	8.682	6.379	4.073
1st Order Decay	12.730	12.729	12.724	12.700	12.612	12.352	11.730	10.533	8.682	6.379	4.073
Inst. Reaction	12.730	12.729	12.724	12.700	12.612	12.352	11.730	10.533	8.682	6.379	4.073
Field Data from Site											



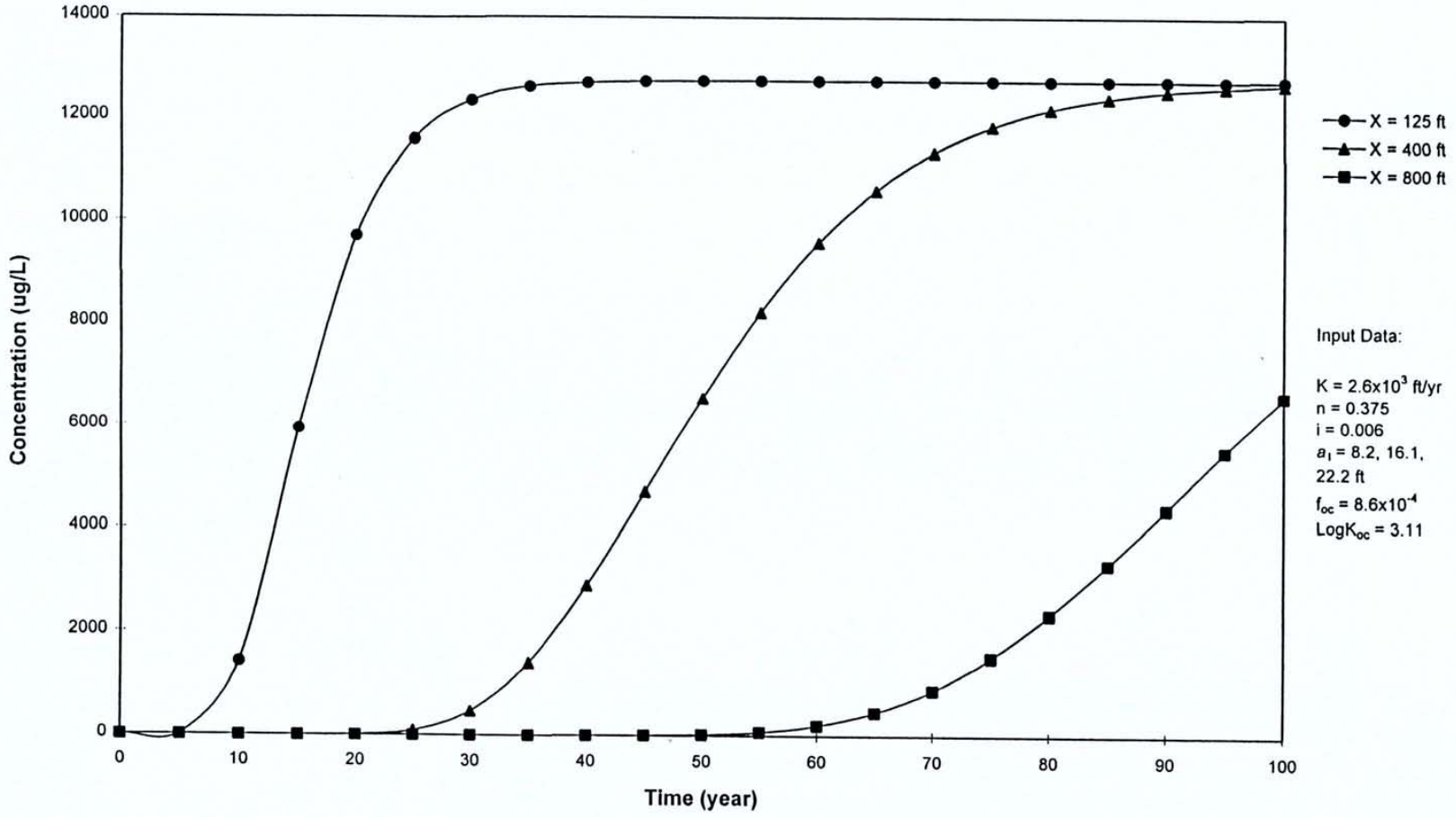
Calculate Animation

Time: 6.00 Years

Return to Input

Recalculate This Sheet

Breakthrough Curve
(Naphthalene - South)

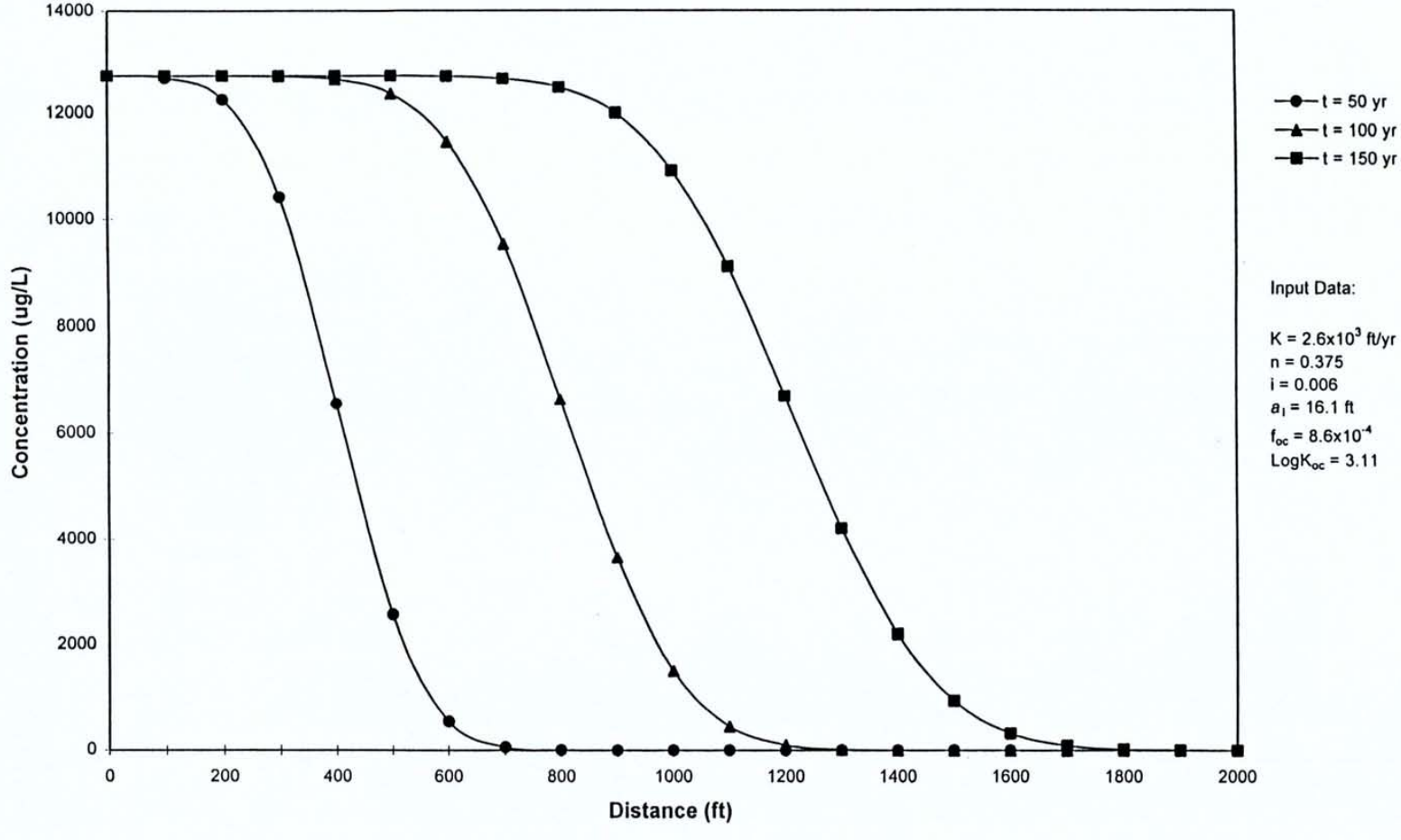


Input Data:

$K = 2.6 \times 10^{3}$ ft/yr
n = 0.375
i = 0.006
a_l = 8.2, 16.1, 22.2 ft
$f_{oc} = 8.6 \times 10^{-4}$
$\text{Log}K_{oc} = 3.11$

c:\jrh\socav\118-11.nat

Breakthrough Curve
(Naphthalene - South)



Input Data:

$K = 2.6 \times 10^{3}$ ft/yr
n = 0.375
i = 0.006
a_l = 16.1 ft
$f_{oc} = 8.6 \times 10^{-4}$
$\text{Log}K_{oc} = 3.11$

c:\jrh\socav\118-11.nat

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Naphthalene

Data Input Instructions:

115 ↑ or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	8.2	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

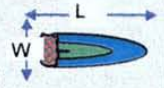
Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	0.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	210	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	15	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

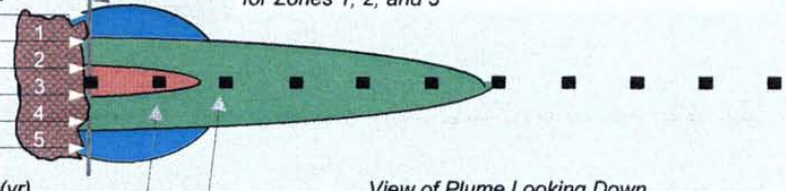
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	12.73
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
21	
42	
63	
84	
105	
126	
147	
168	
189	
210	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

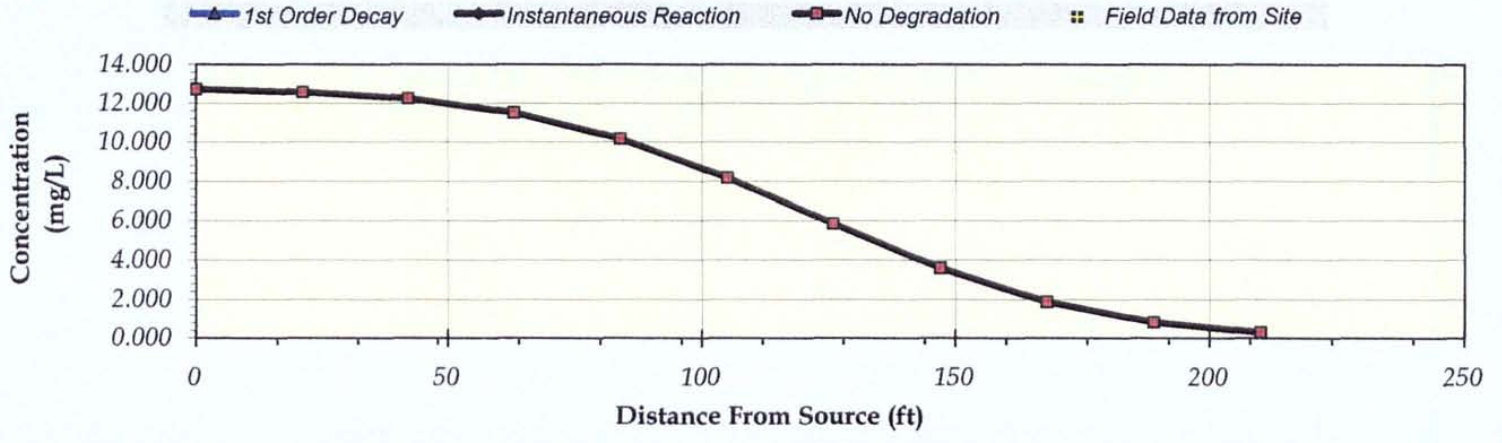
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - SOUTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	21	42	63	84	105	126	147	168	189	210
No Degradation	12.730	12.574	12.250	11.514	10.167	8.183	5.834	3.596	1.881	0.823	0.298
1st Order Decay	12.730	12.574	12.250	11.514	10.167	8.183	5.834	3.596	1.881	0.823	0.298
Inst. Reaction	12.730	12.574	12.250	11.514	10.167	8.183	5.834	3.596	1.881	0.823	0.298
Field Data from Site											



Calculate Animation

Time: 15.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Naphthalene

Data Input Instructions:

115 ↑ or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	16.1	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	0.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	500	(ft)	L
Modeled Area Width*	0	(ft)	W
Simulation Time*	50	(yr)	

6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

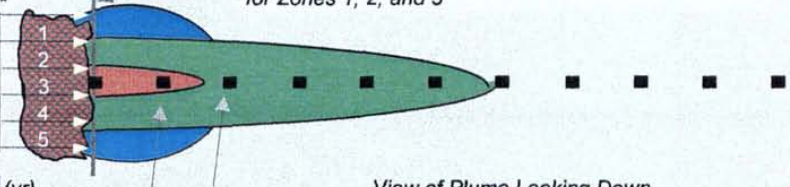
Source Zones:

	Width* (ft)	Conc. (mg/L)*
1		
2		
3	200	12.73
4	0	0
5	0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
50	
100	
150	
200	
250	
300	
350	
400	
450	
500	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

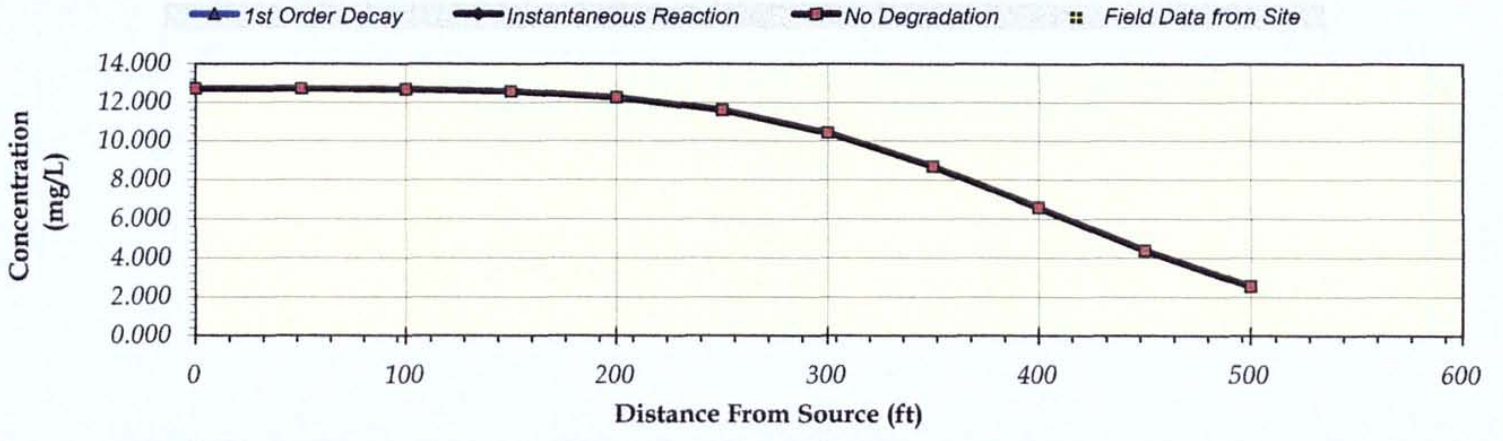
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - SOUTH AREA

	Distance from Source (ft)										
TYPE OF MODEL	0	50	100	150	200	250	300	350	400	450	500
No Degradation	12.730	12.718	12.681	12.566	12.264	11.610	10.438	8.699	6.562	4.390	2.561
1st Order Decay	12.730	12.718	12.681	12.566	12.264	11.610	10.438	8.699	6.562	4.390	2.561
Inst. Reaction	12.730	12.718	12.681	12.566	12.264	11.610	10.438	8.699	6.562	4.390	2.561
Field Data from Site											



Calculate Animation

Time: 50.00 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.3*

South Cavalcade
South Area
Naphthalene

Data Input Instructions:

115 ↑ or 0.02 — 1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* — Data used directly in model.

20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	39.8	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.00571	(ft/ft)
Porosity	n	0.375	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	22.2	(ft)
Transverse Dispersivity*	alpha y	0.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	425	(ft)

3. ADSORPTION

Retardation Factor*	R	4.9	(-)
or		↑ or	
Soil Bulk Density	rho	1.325	(kg/l)
Partition Coefficient	Koc	1290	(L/kg)
FractionOrganicCarbon	foc	8.60E-04	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	0.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	0	(ft)
Simulation Time*	100	(yr)

6. SOURCE DATA

Source Thickness in Sat.Zone* 15 (ft)

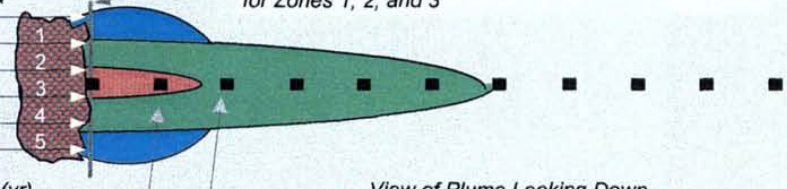
Source Zones:

Width* (ft)	Conc. (mg/L)*
200	12.73
0	0
0	0

Source Decay (see Help):

SourceHalflife*	Infinite	(yr)
Soluble Mass	↑ or	
In NAPL, Soil	Infinite	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
Concentration (mg/L)											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

Recalculate This Sheet

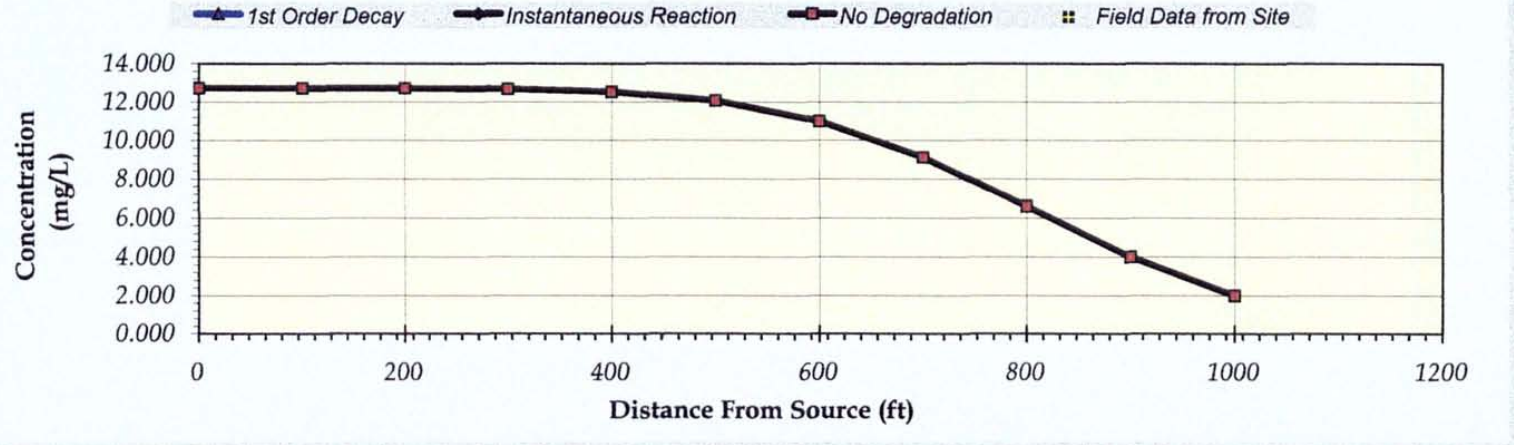
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED NAPHTHALENE CONCENTRATION (mg/l) - SOUTH AREA

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	12.730	12.729	12.722	12.684	12.533	12.074	11.009	9.130	6.602	4.014	1.993
1st Order Decay	12.730	12.729	12.722	12.684	12.533	12.074	11.009	9.130	6.602	4.014	1.993
Inst. Reaction	12.730	12.729	12.722	12.684	12.533	12.074	11.009	9.130	6.602	4.014	1.993
Field Data from Site											



Calculate Animation

Time: 100.00 Years

Return to Input

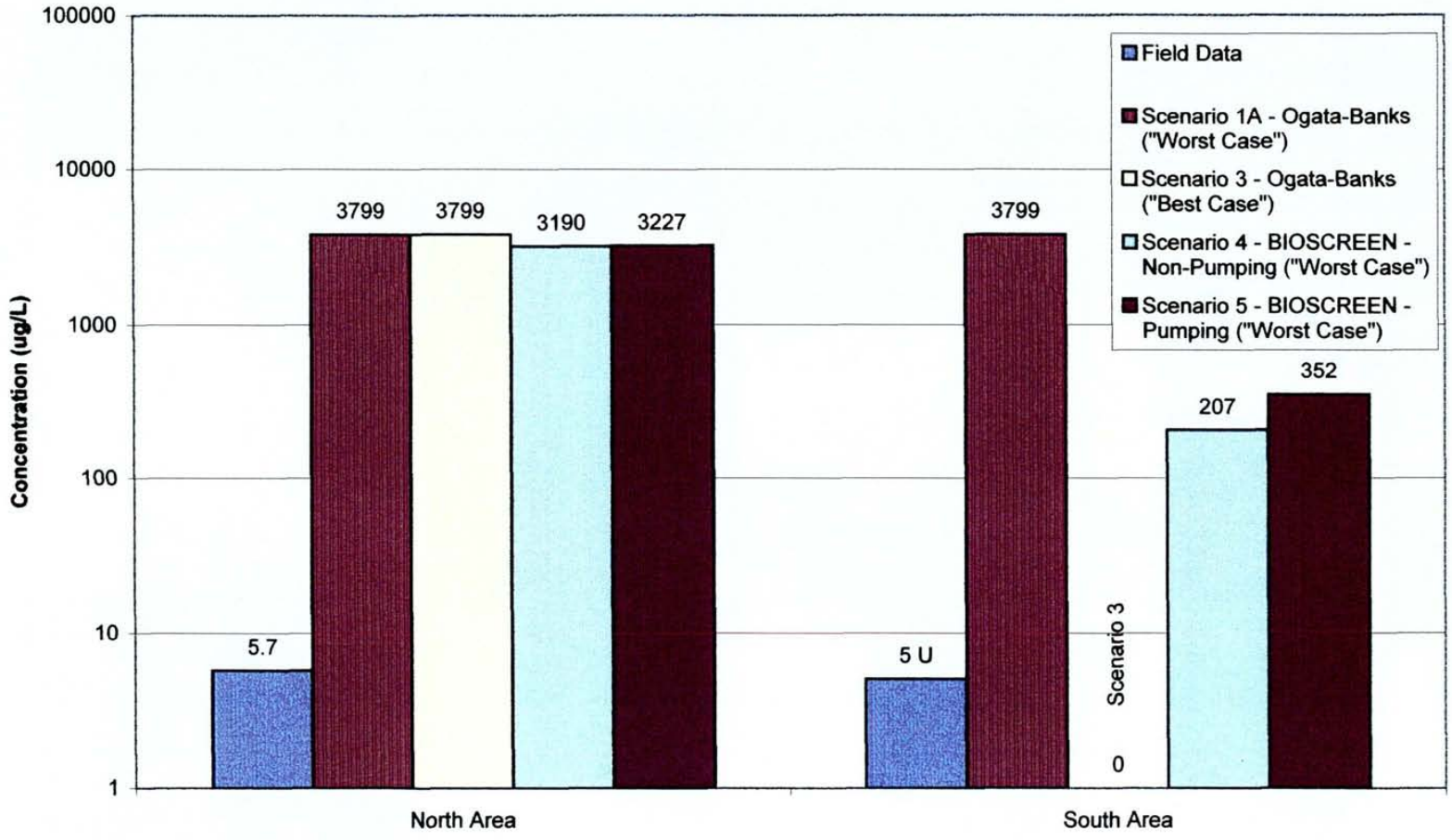
Recalculate This Sheet

APPENDIX Q

COMPARISON OF FIELD DATA TO SIMULATION RESULTS

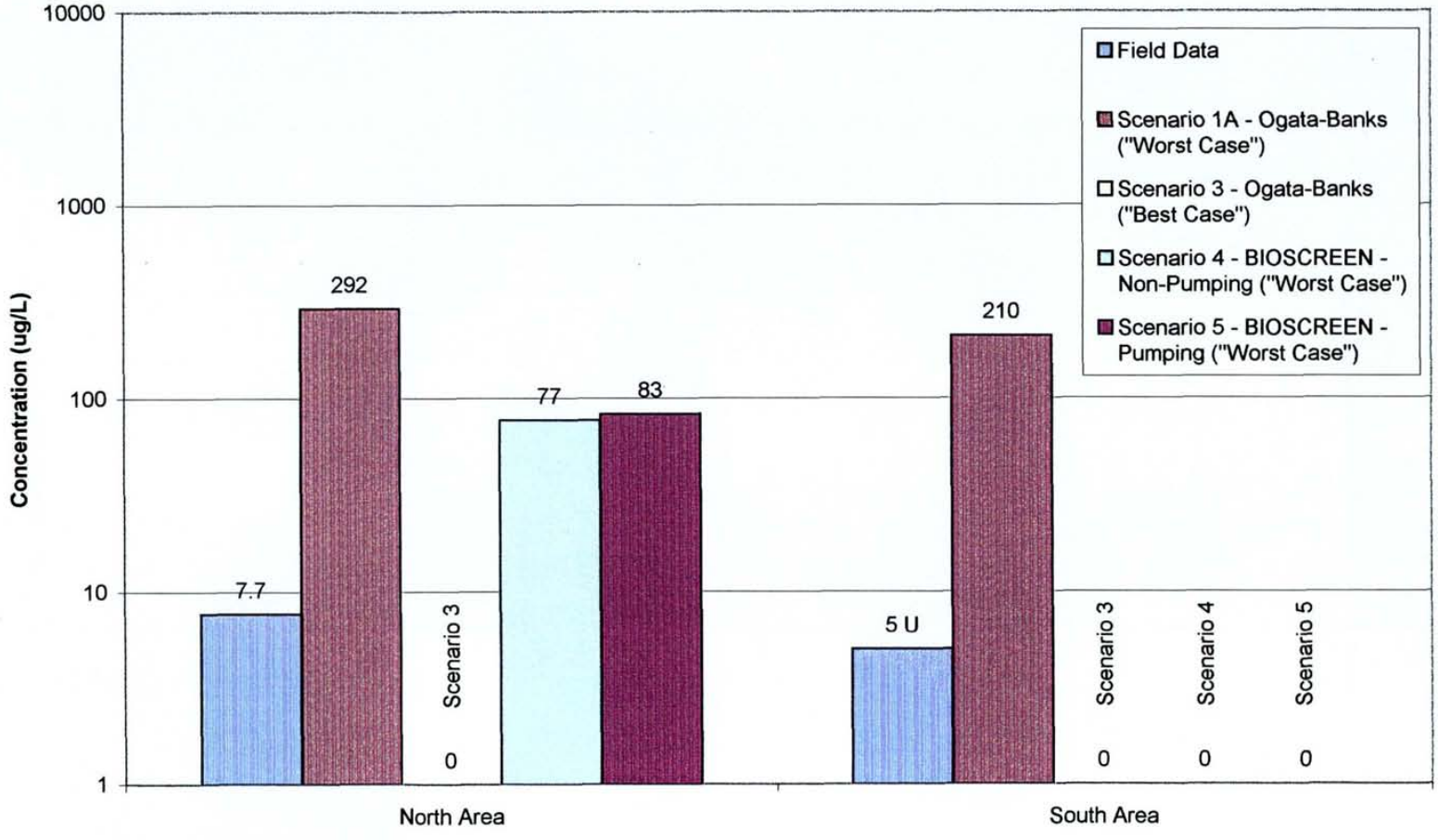
KEY ENVIRONMENTAL INCORPORATED

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Benzene



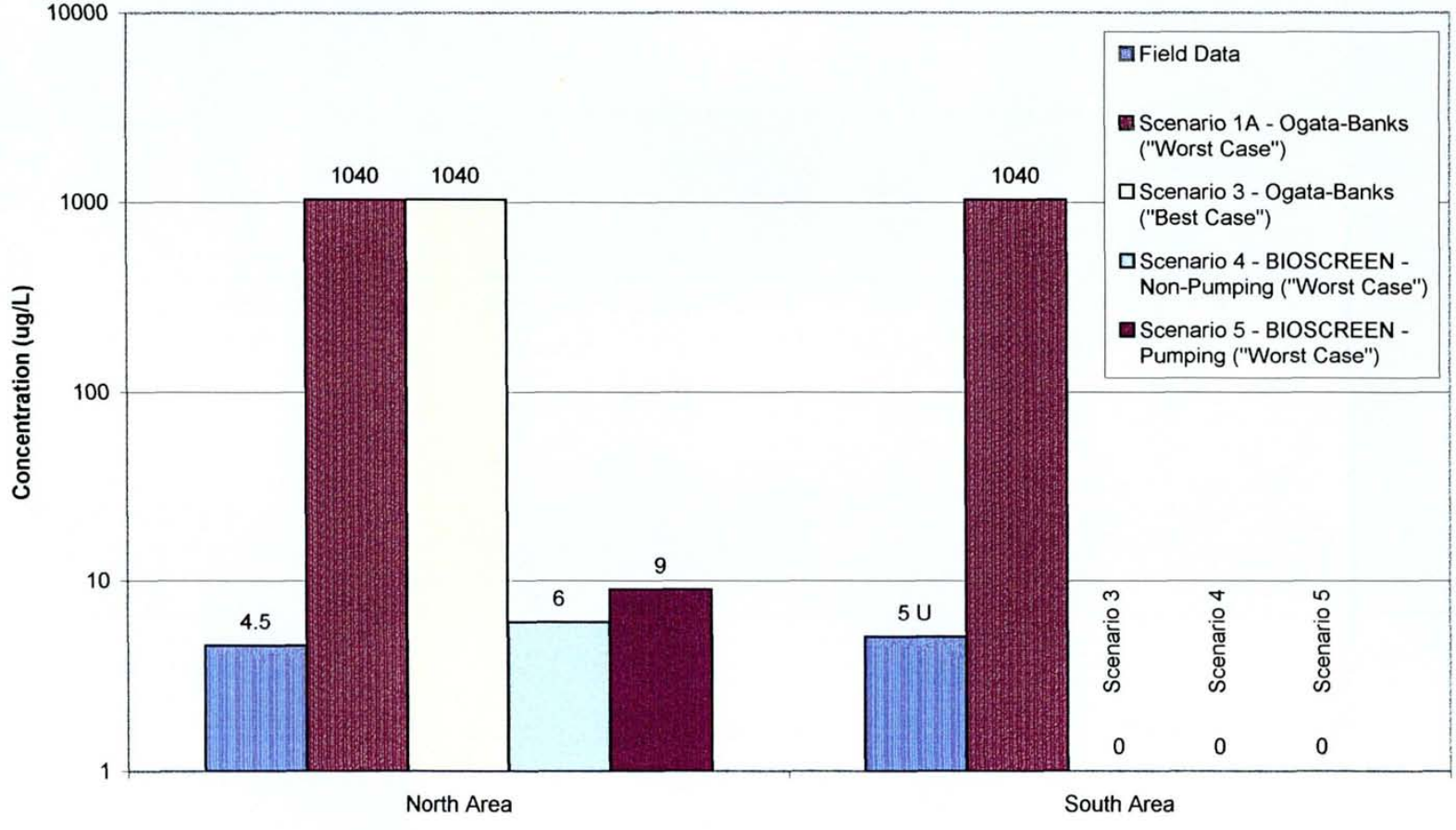
rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Ethylbenzene



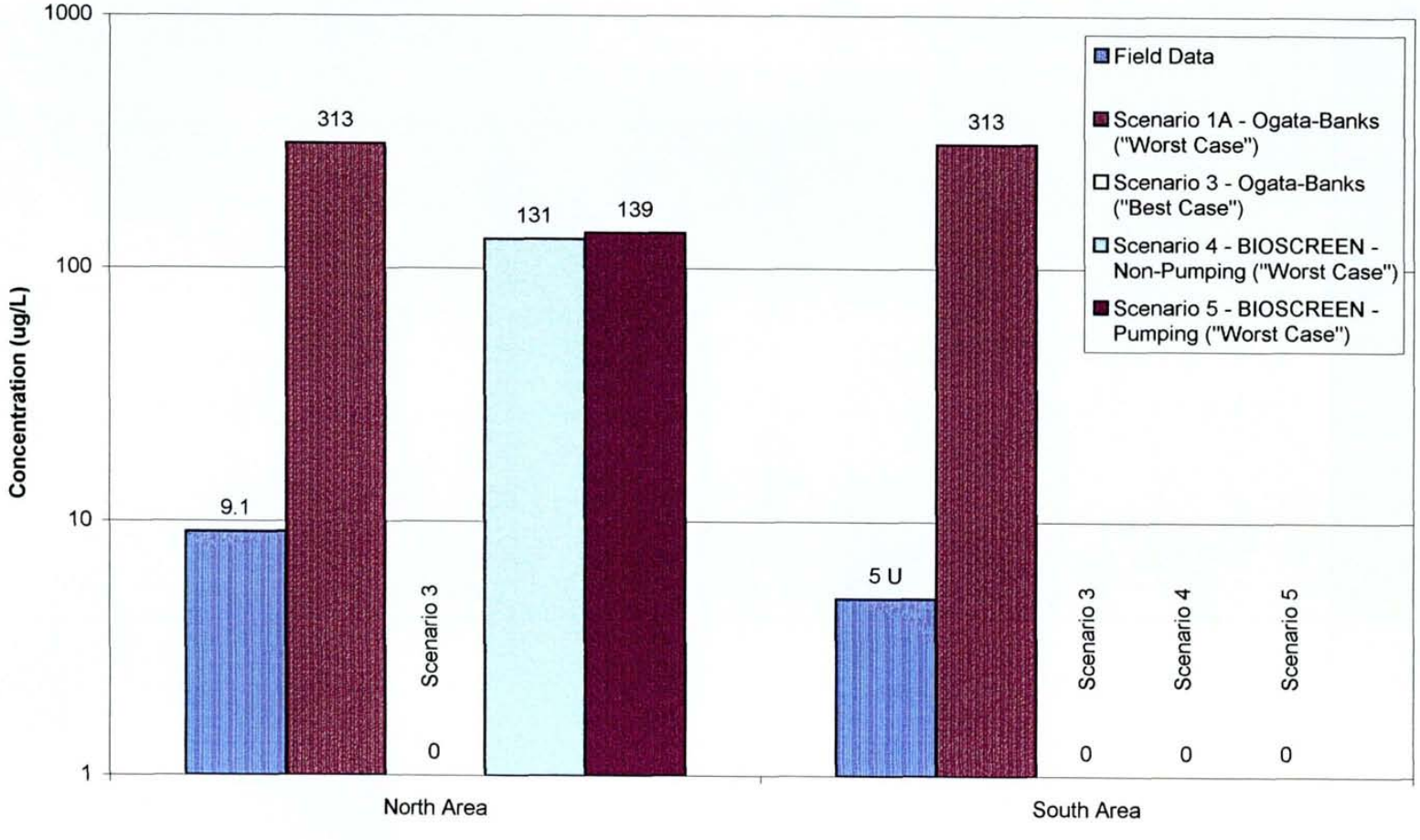
rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Toluene



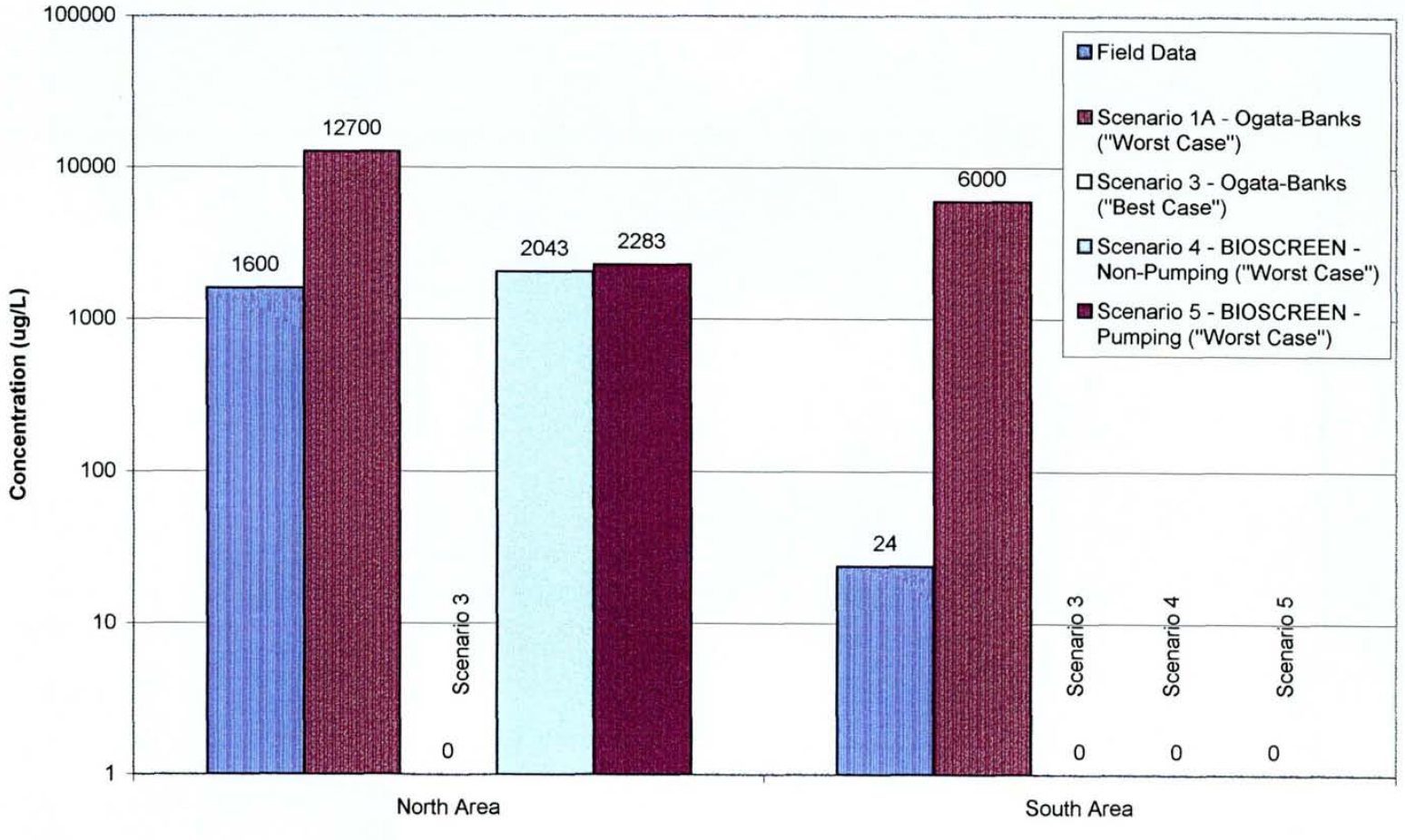
rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Xylene



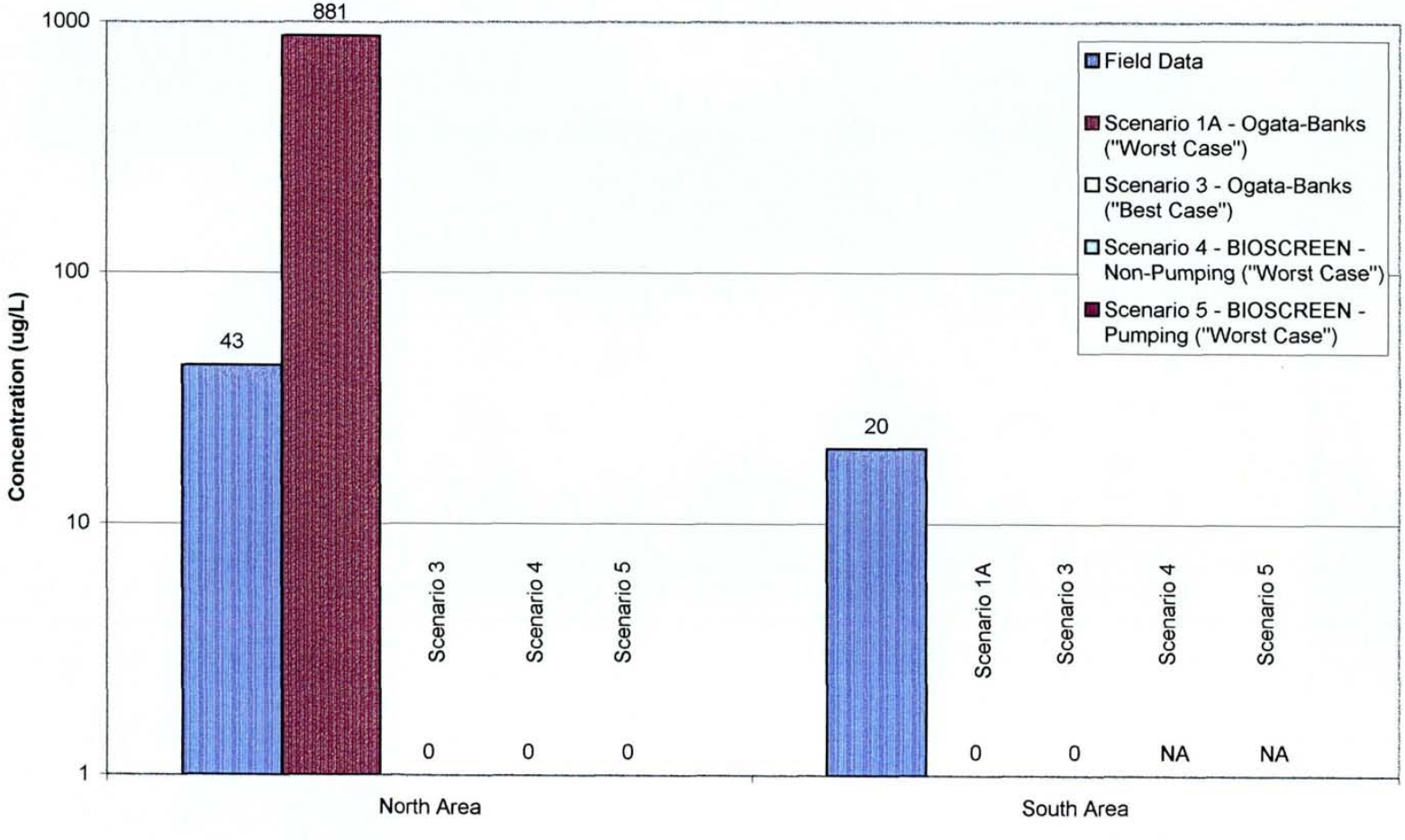
rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Naphthalene



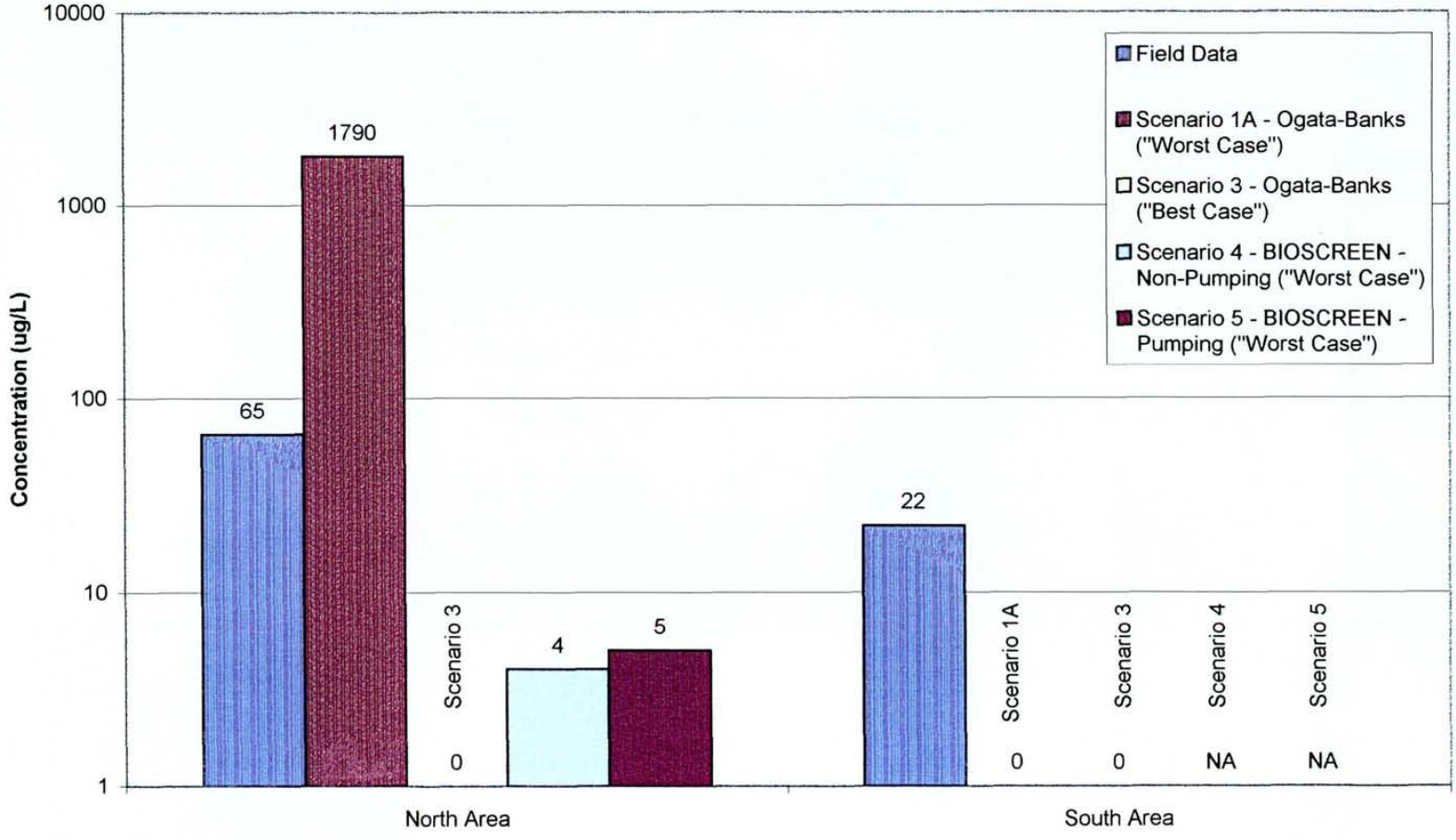
rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Fluorene



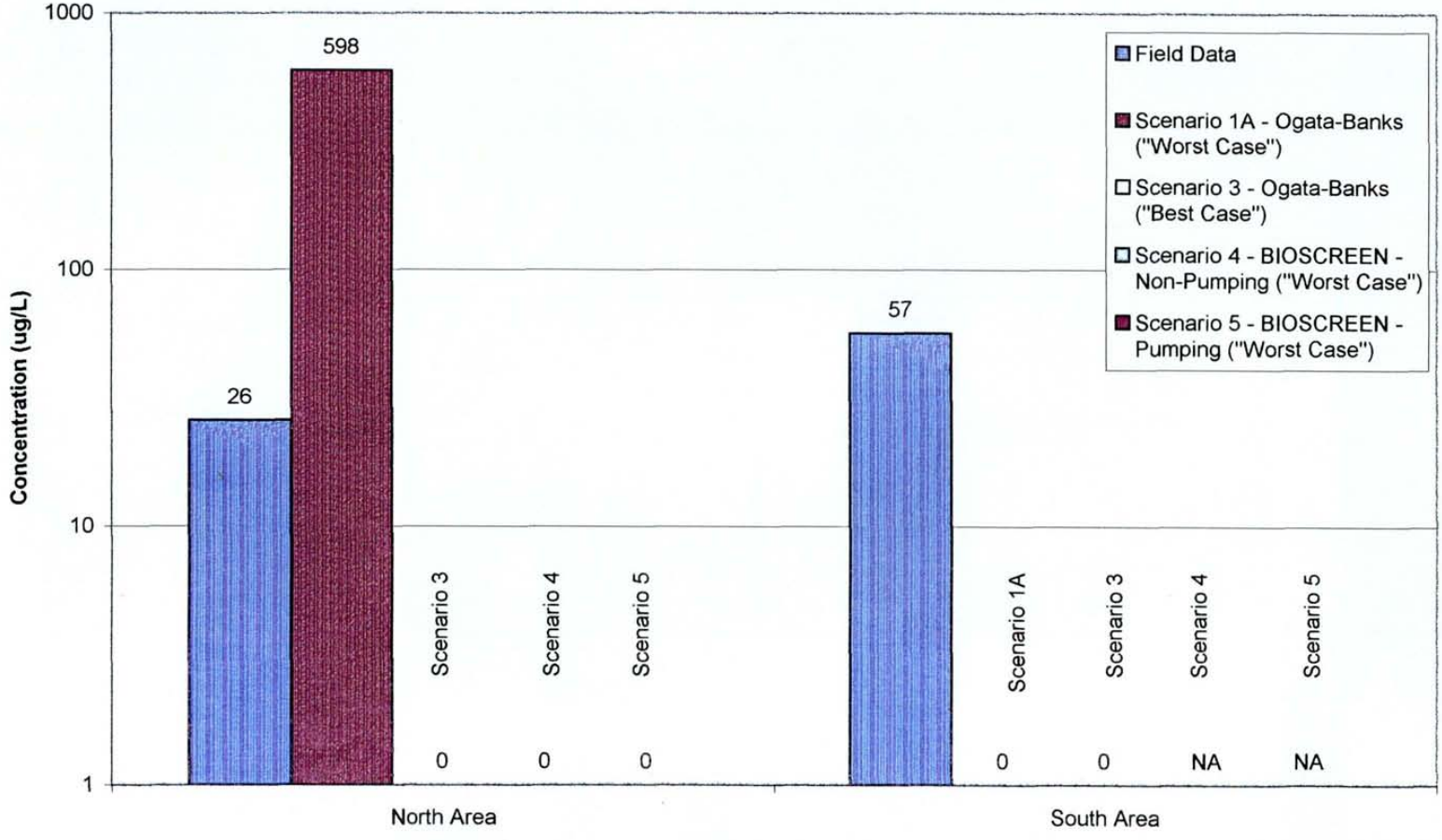
rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Acenaphthene



rjh c:\scav\96-118\datasum.xls

SOUTH CAVALCADE SUPERFUND SITE - HOUSTON, TEXAS
Comparison of Field Data to Simulation Results
Phenanthrene



rjh c:\scav\96-118\datasum.xls